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Basic Principles of Ultrasonic Testing

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Krautrkamer Ultrasonic Systems

Agfa NDT GmbH, Hürth, Germany

1986 - 2002

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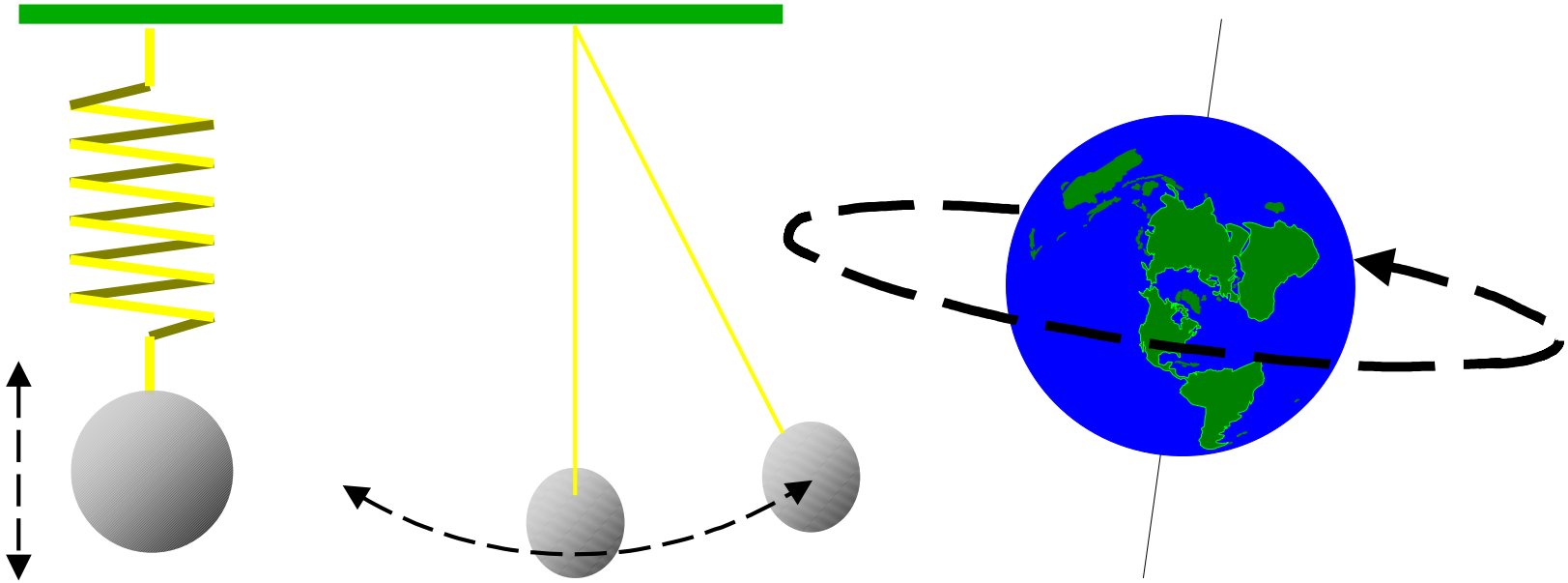
Examples of oscillation

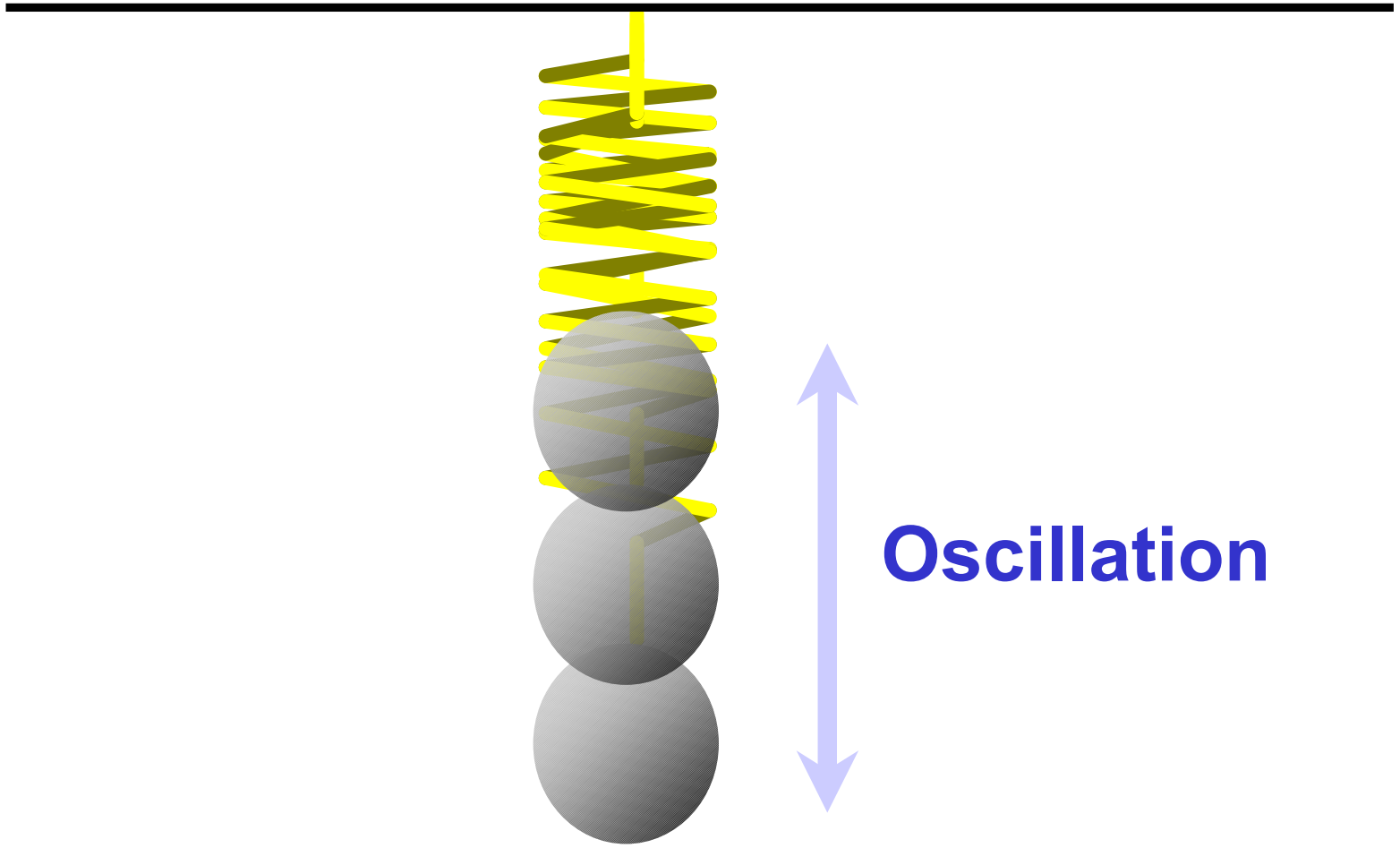
ball on a spring

pendulum

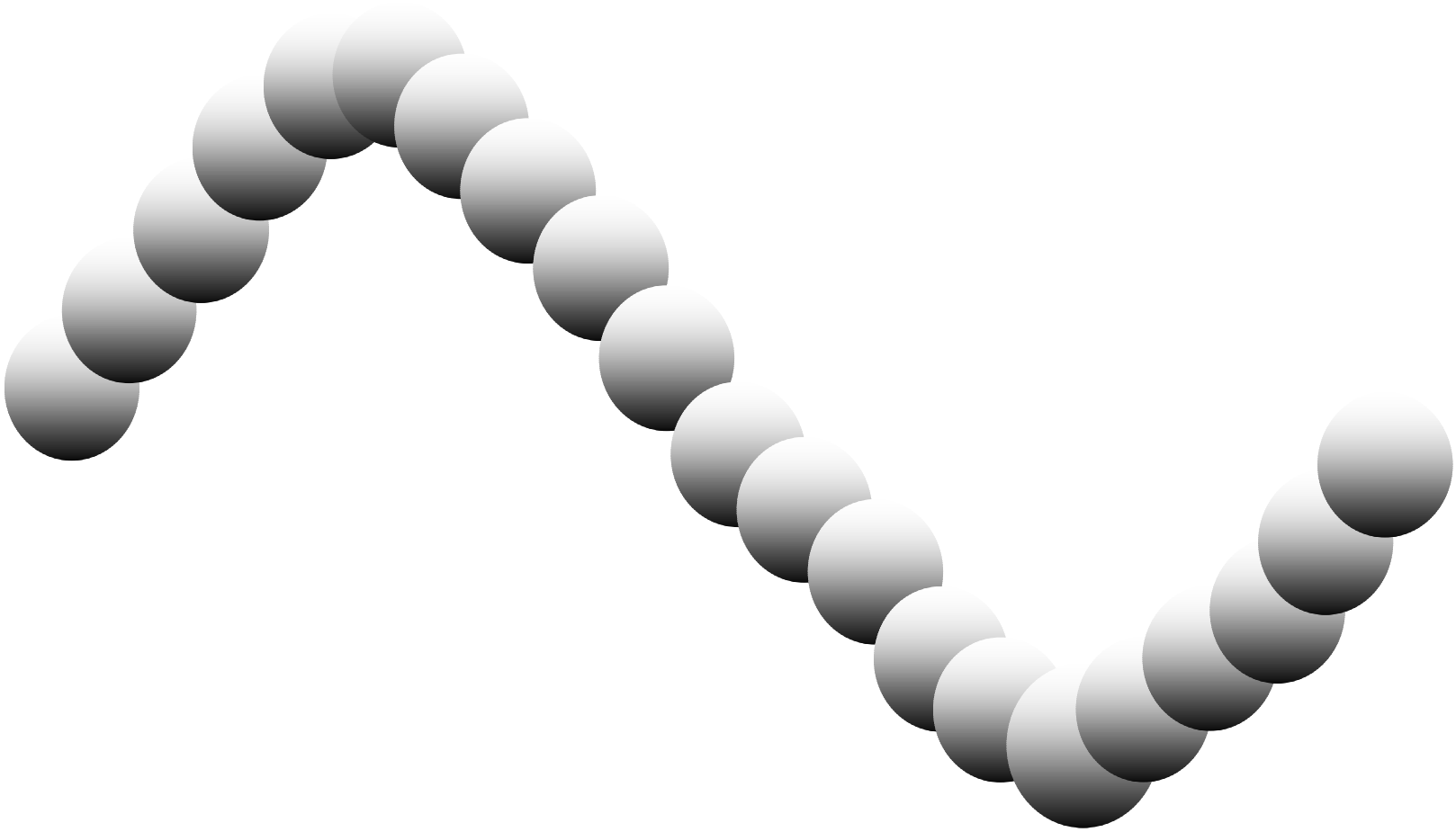
rotating earth



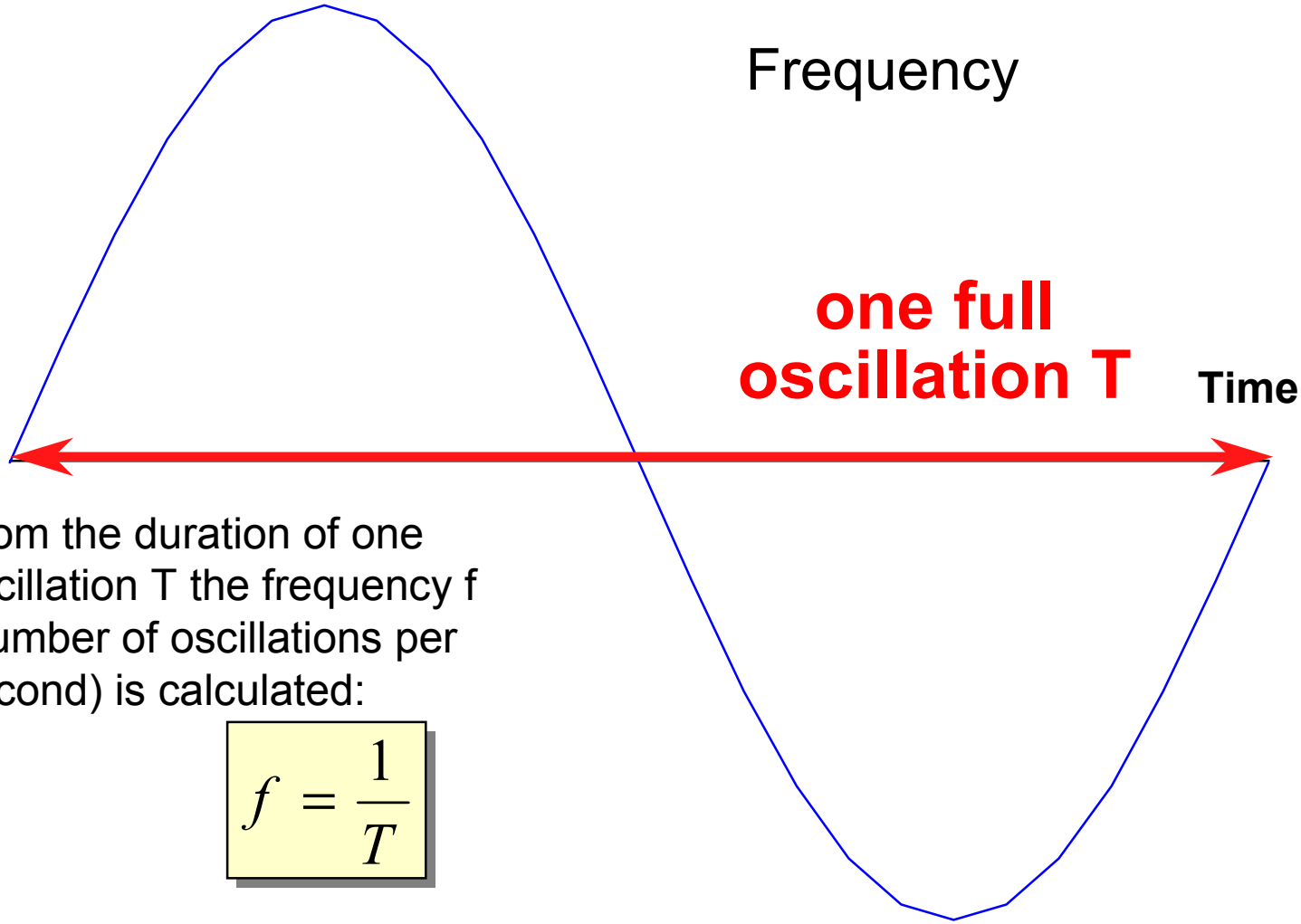
The ball starts to oscillate as soon as it is pushed


Oscillation

Movement of the ball over time

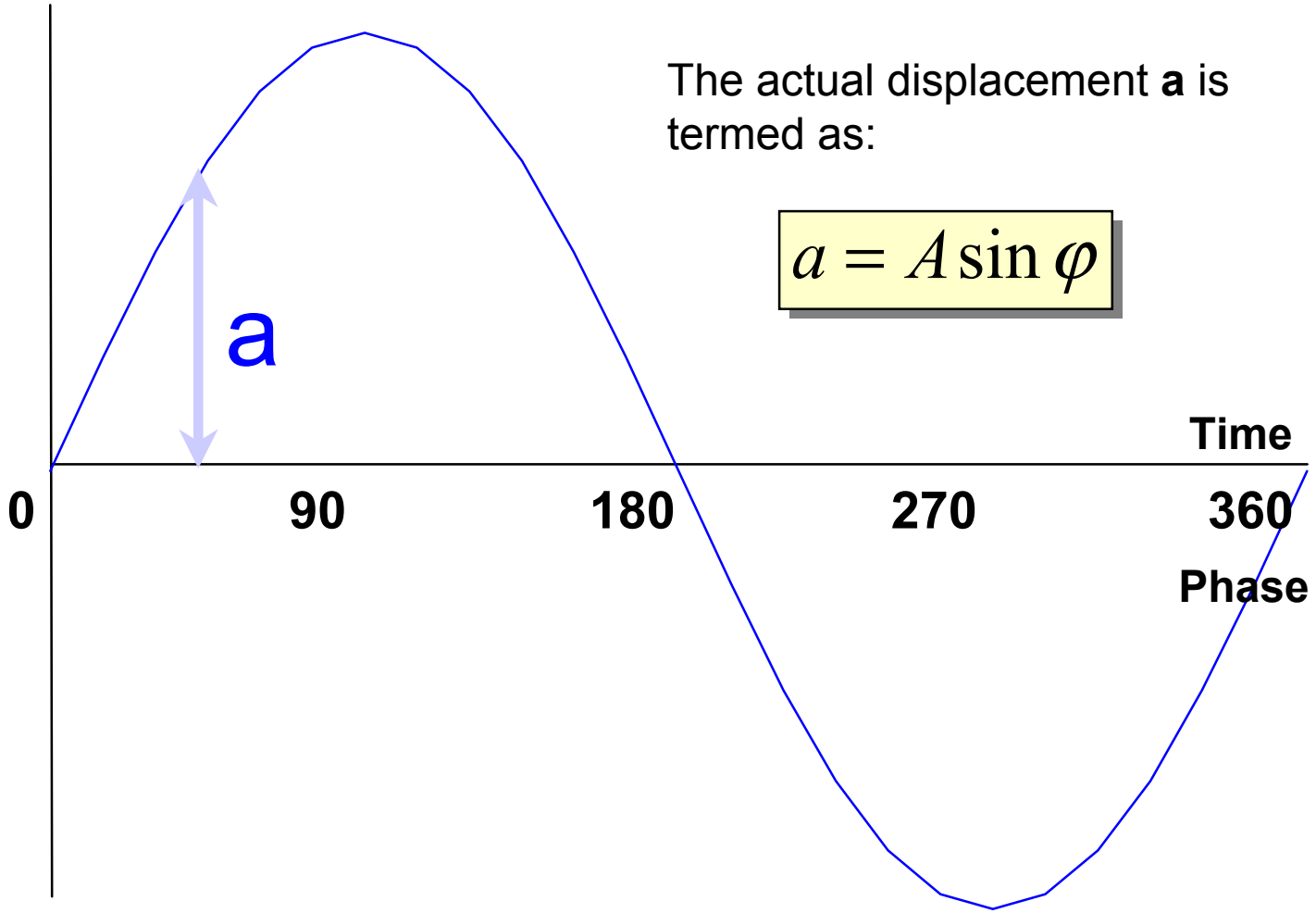


Frequency



From the duration of one oscillation T the frequency f (number of oscillations per second) is calculated:

$$f = \frac{1}{T}$$



The actual displacement **a** is termed as:

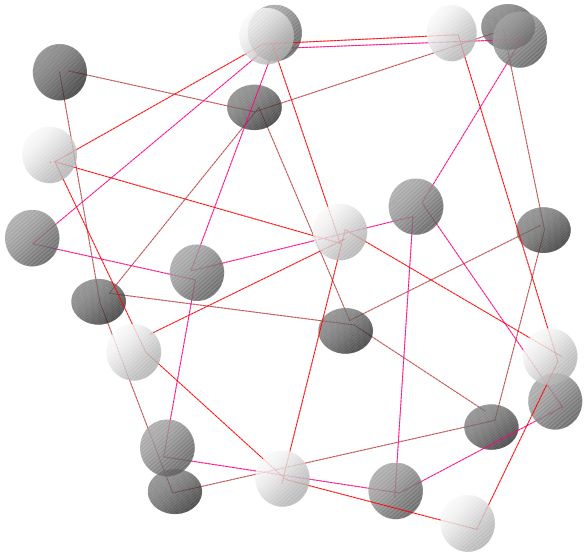
$$a = A \sin \varphi$$

Spectrum of sound

Frequency range Hz	Description	Example
0 - 20	Infrasound	Earth quake
20 - 20.000	Audible sound	Speech, music
> 20.000	Ultrasound	Bat, Quartz crystal

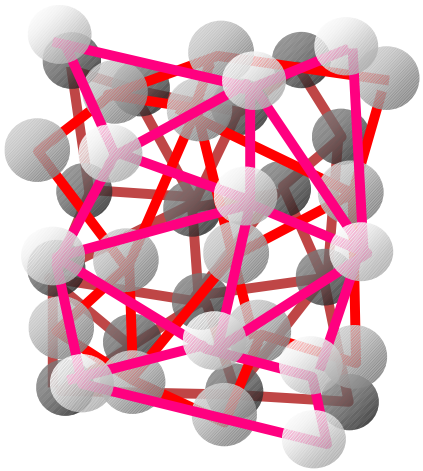
Atomic structures

gas



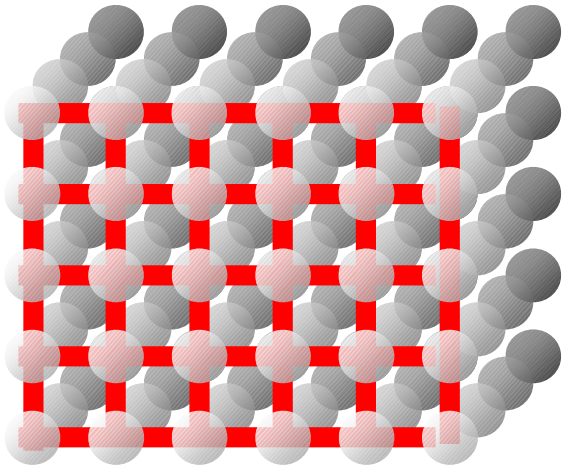
- low density
- weak bonding forces

liquid



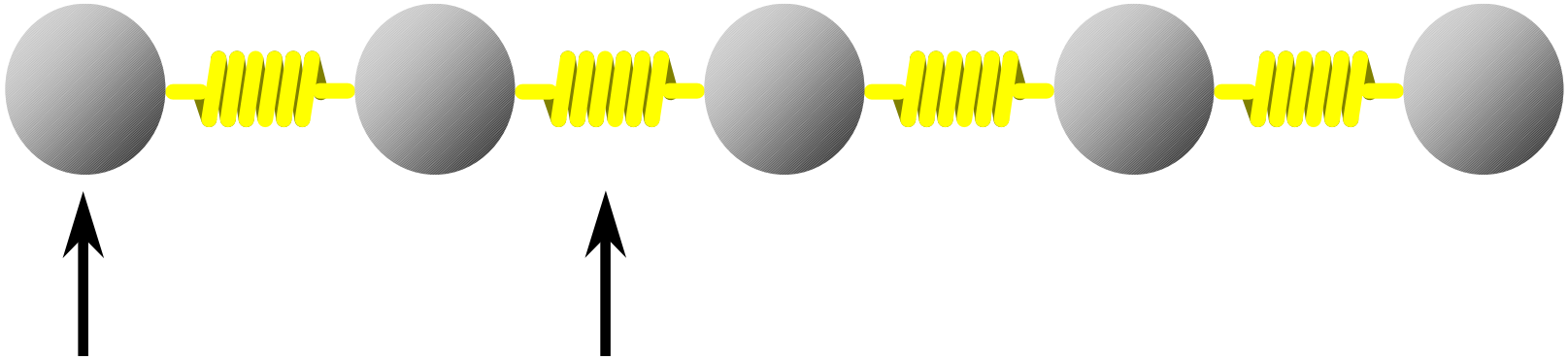
- medium density
- medium bonding forces

solid



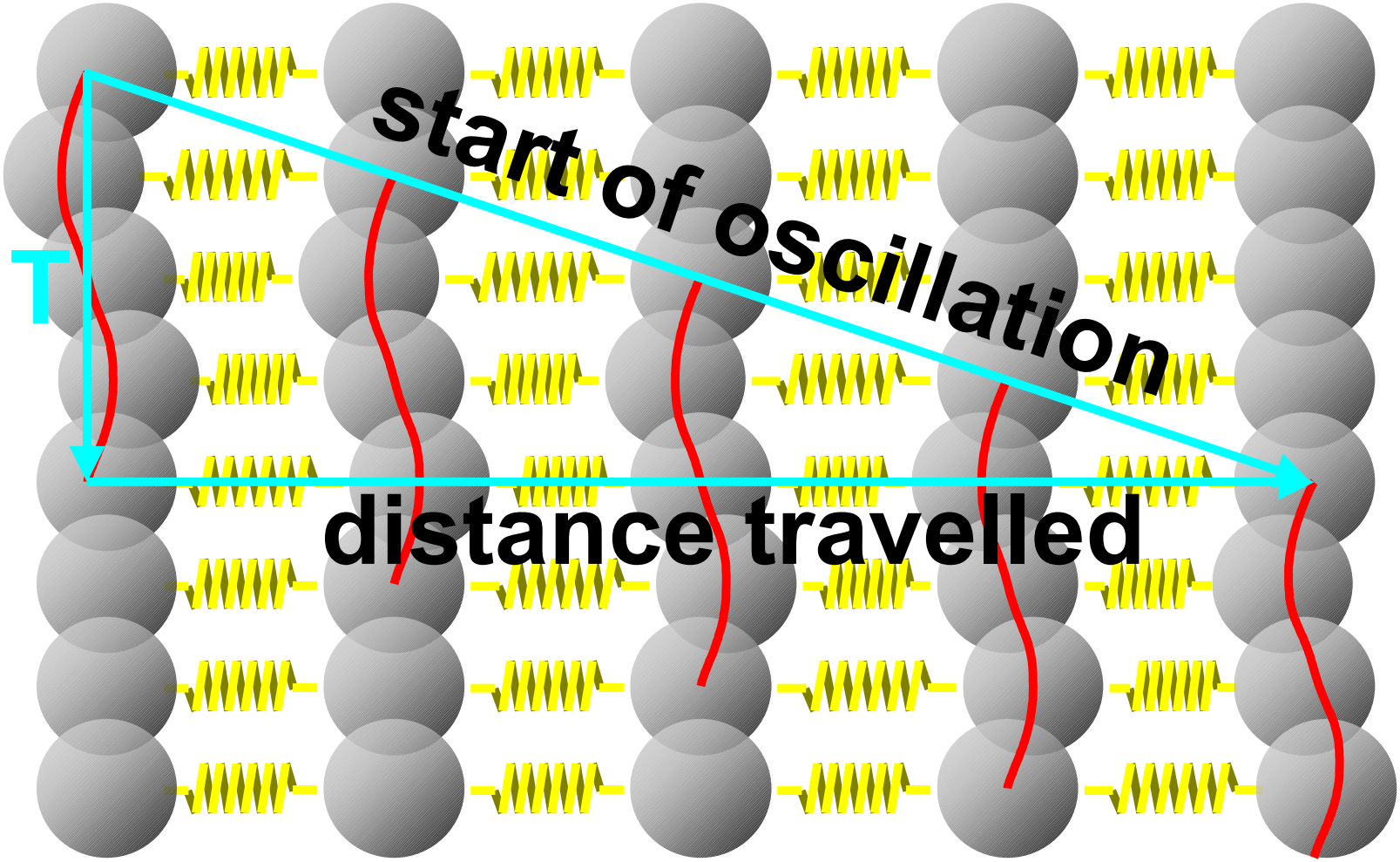
- high density
- strong bonding forces
- crystallographic structure

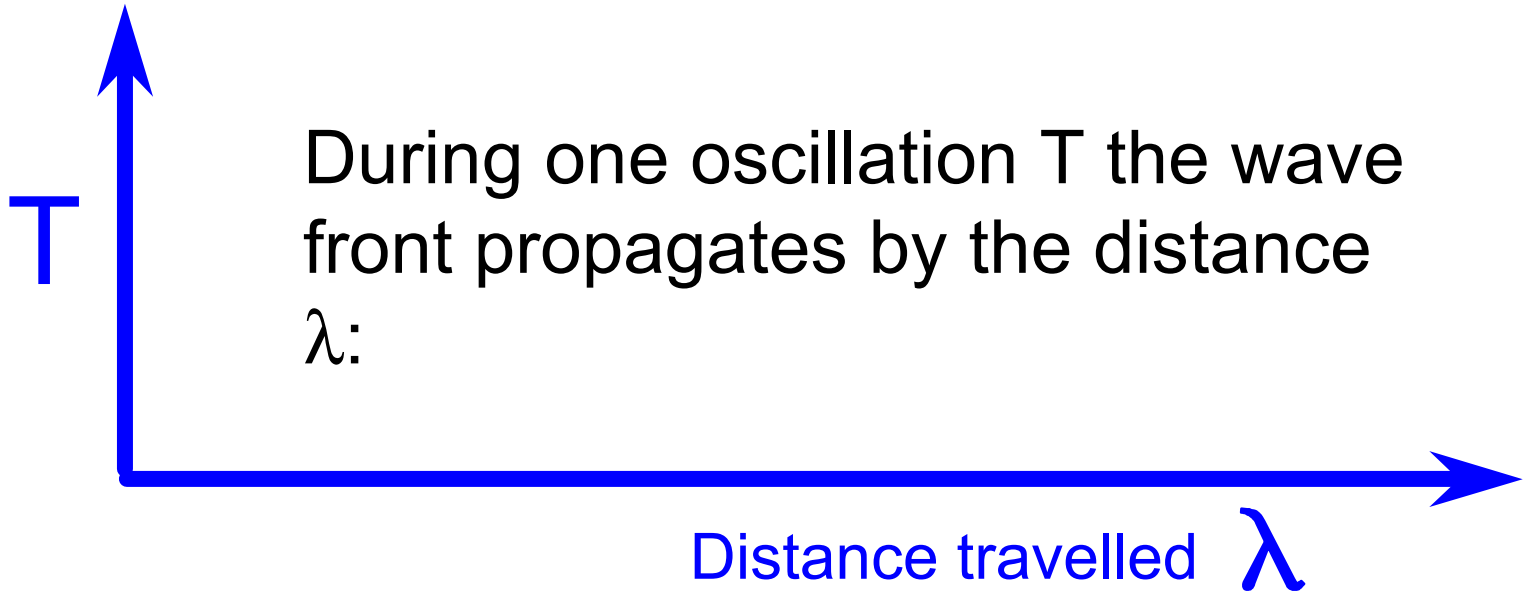
Understanding wave propagation:



Ball = atom

Spring = elastic bonding force


start of oscillation
T
distance travelled

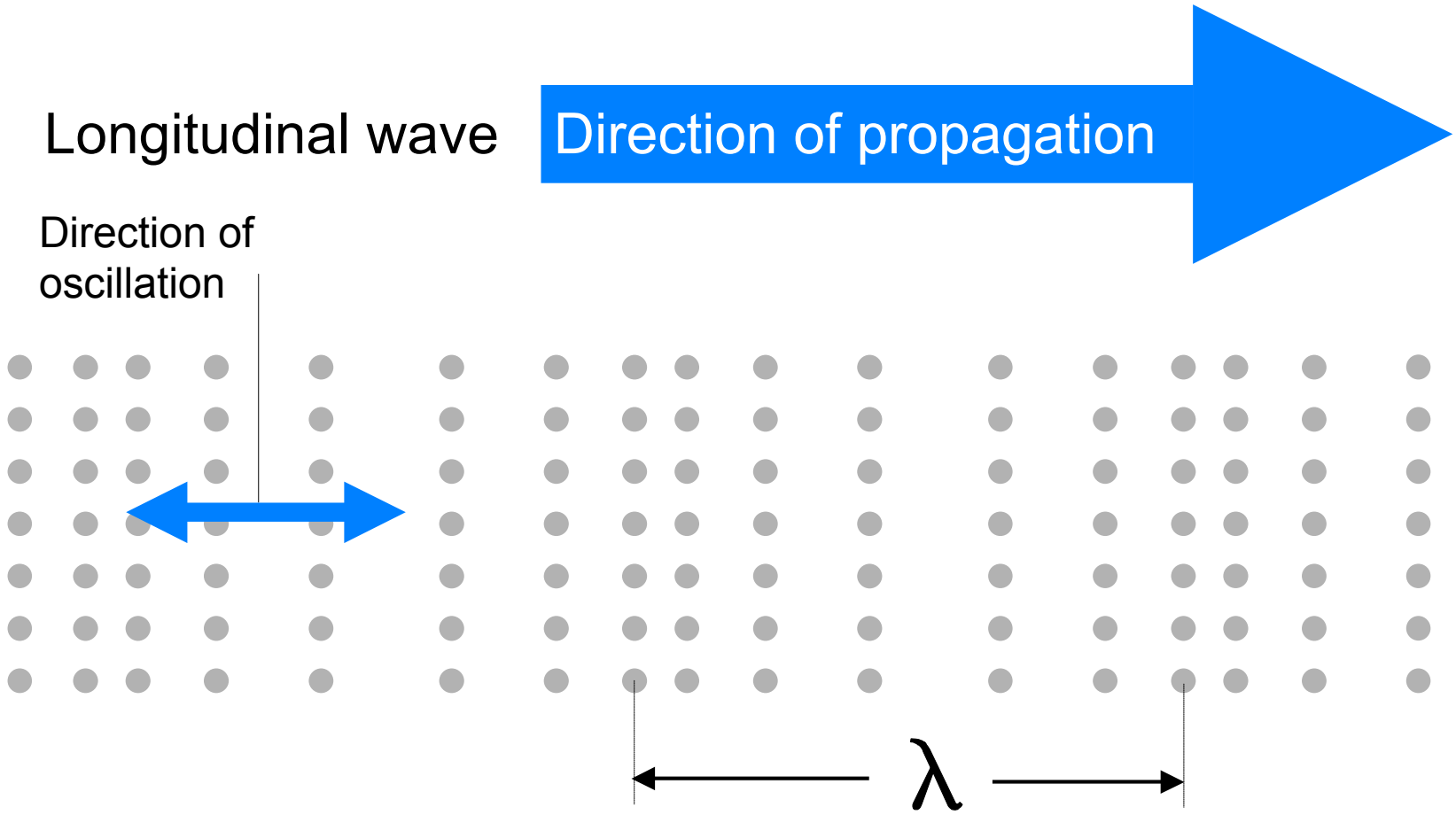


From this we derive:

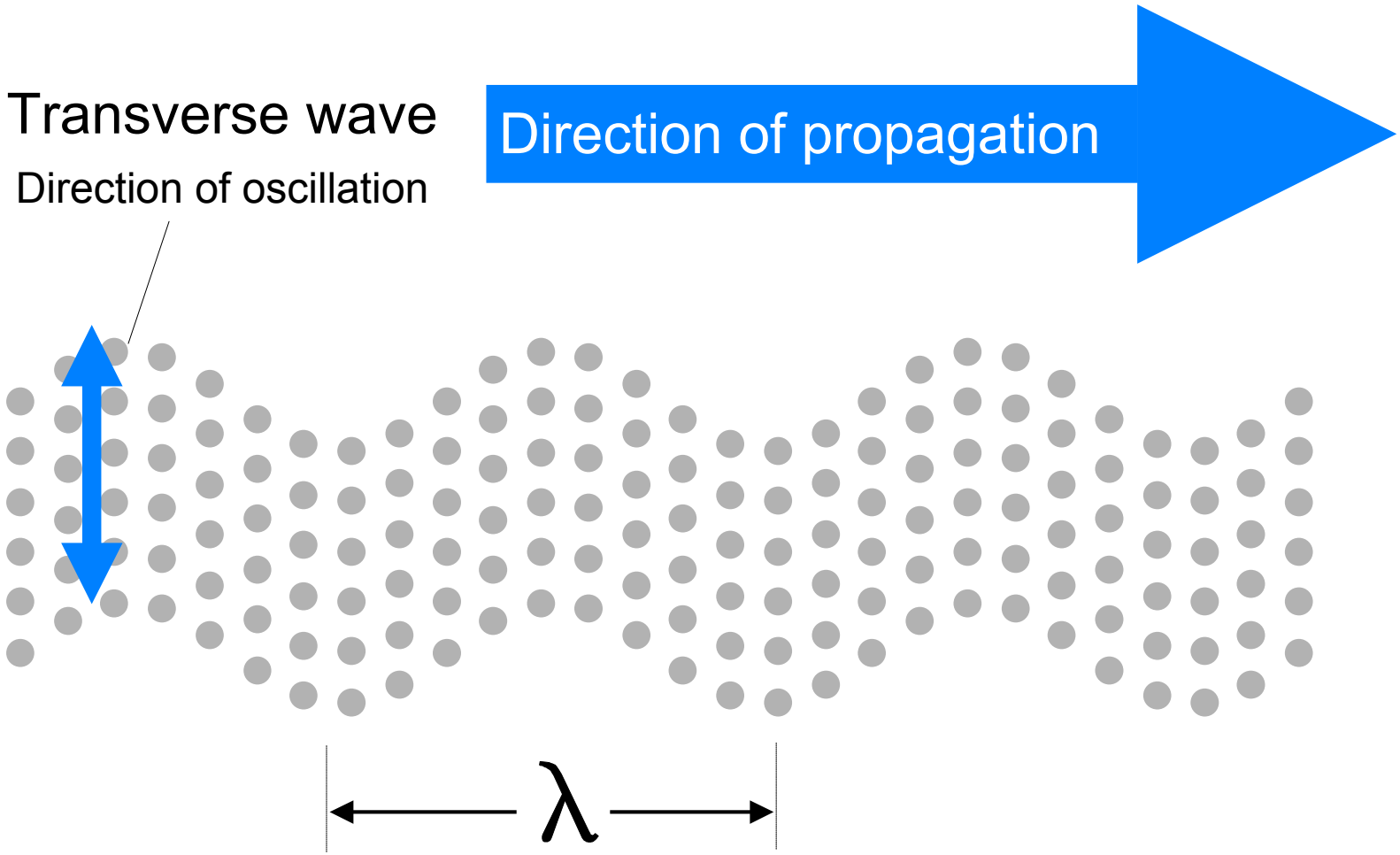
$$c = \frac{\lambda}{T}$$ or $$c = \lambda f$$

Wave equation

Sound propagation



Sound propagation



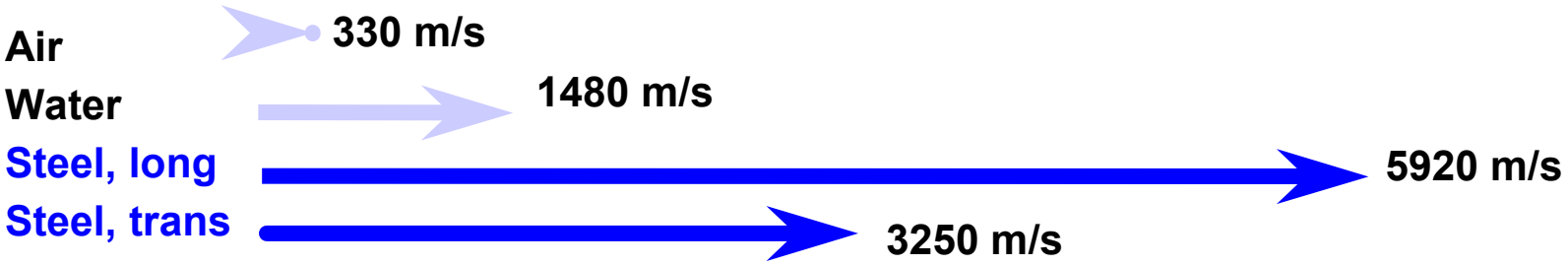
Wave propagation

Longitudinal waves propagate in all kind of materials.

Transverse waves only propagate in solid bodies.

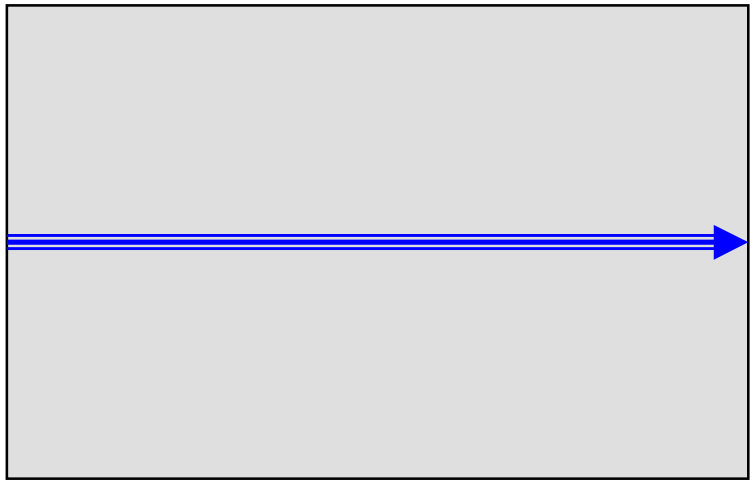
Due to the different type of oscillation, transverse waves
travel at lower speeds.

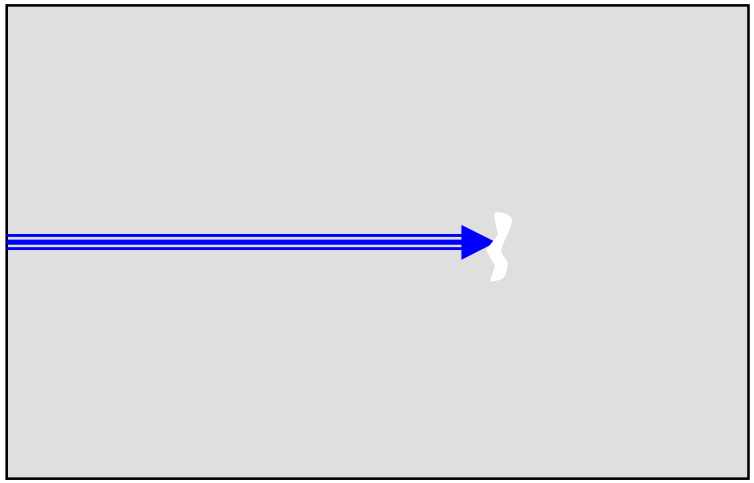
Sound velocity mainly depends on the density and E-modulus of the material.



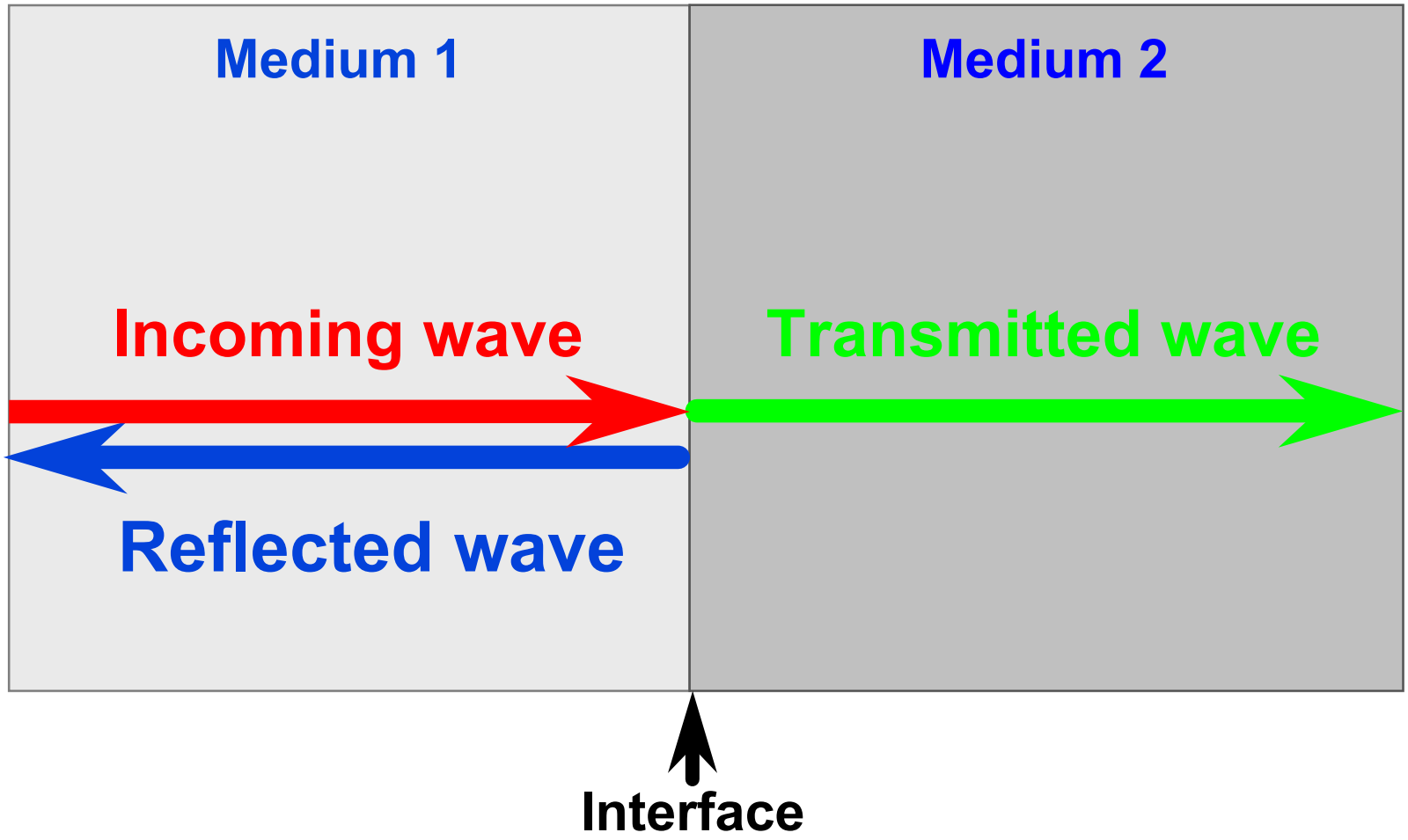
Reflection and Transmission

As soon as a sound wave comes to a change in material characteristics ,e.g. the surface of a workpiece, or an internal inclusion, wave propagation will change too:

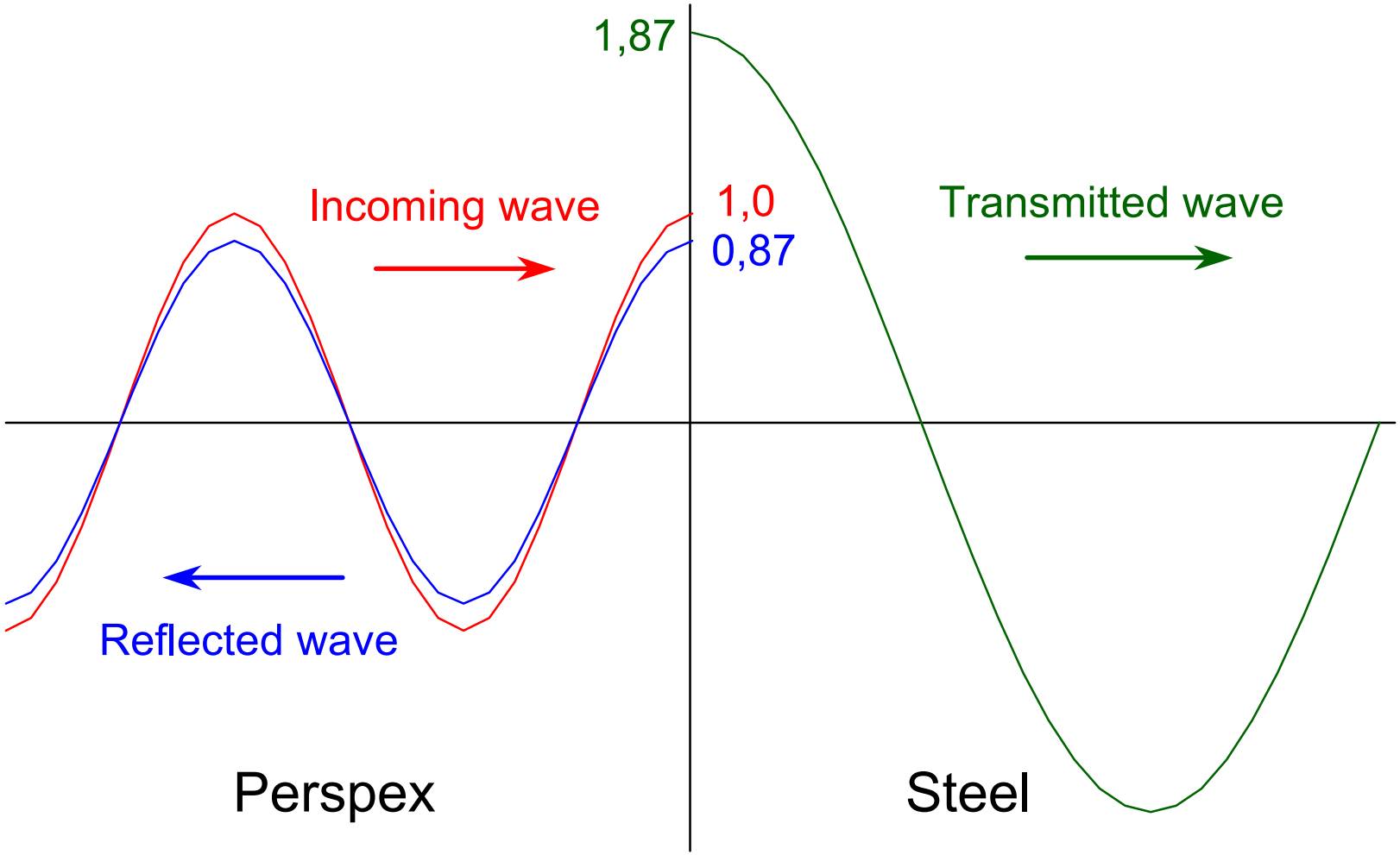




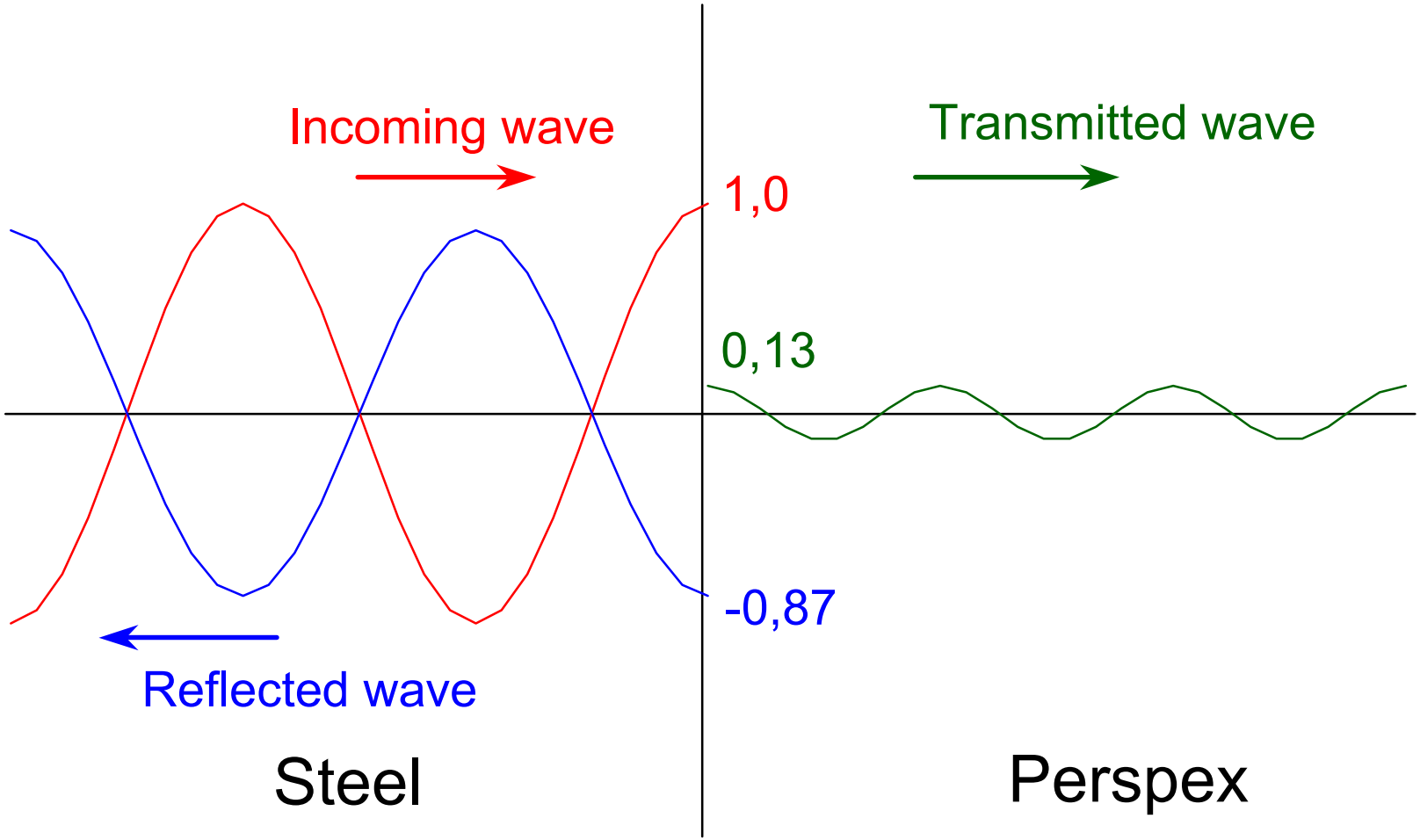
Behaviour at an interface



Reflection + Transmission: Perspex - Steel



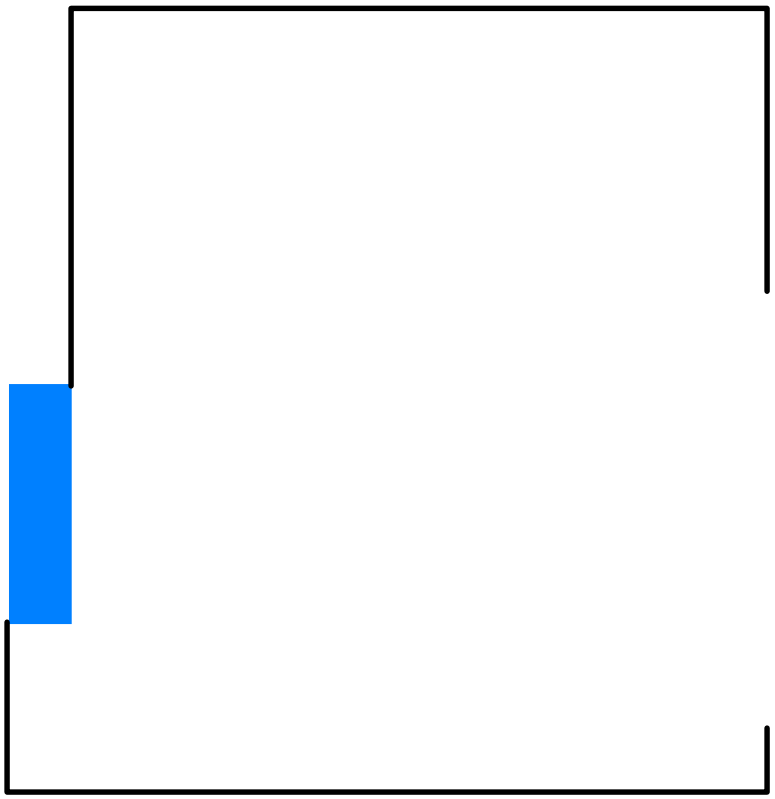
Reflection + Transmission: Steel - Perspex



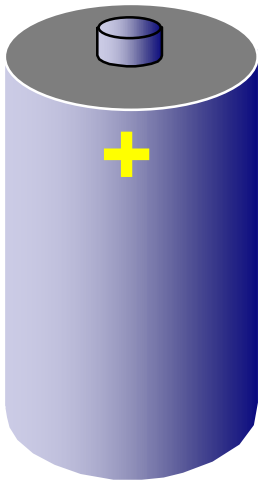
Amplitude of sound transmissions:

Water - Steel	Copper - Steel	Steel - Air
• Strong reflection • Double transmission	• No reflection • Single transmission	• Strong reflection with inverted phase • No transmission

Piezoelectric Effect

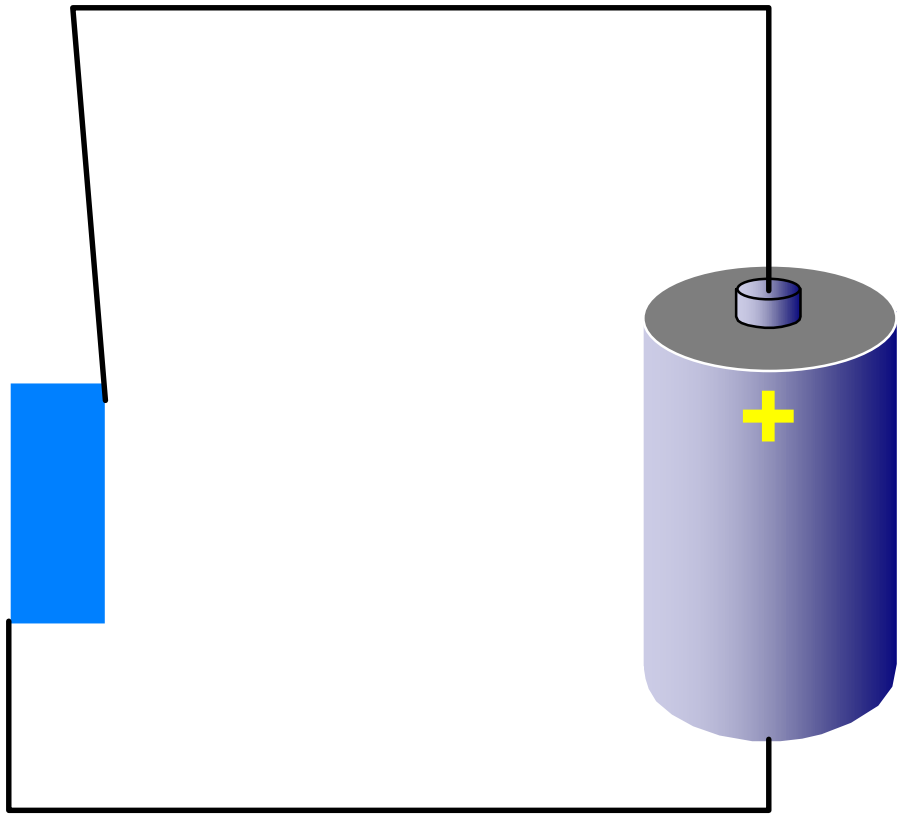


Piezoelectrical
Crystal (Quartz)



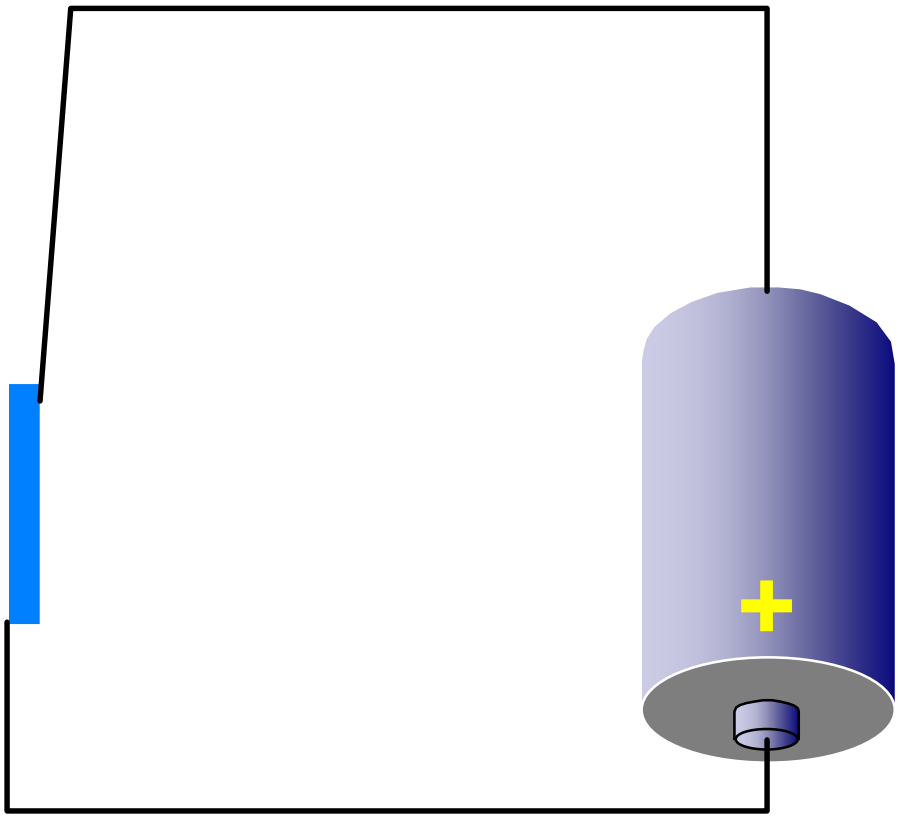
Battery

Piezoelectric Effect



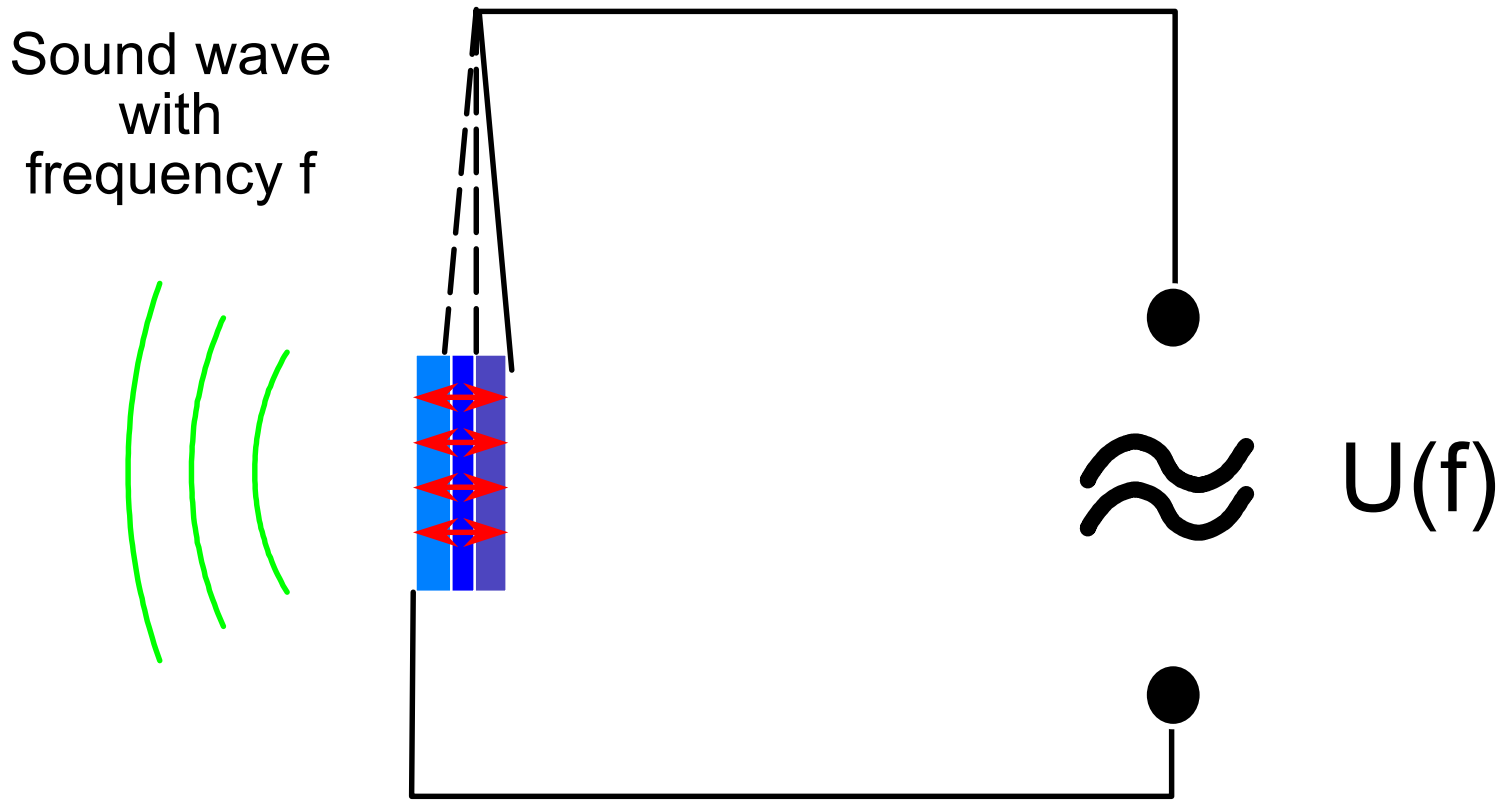
The crystal gets thicker, due to a distortion of the crystal lattice

Piezoelectric Effect



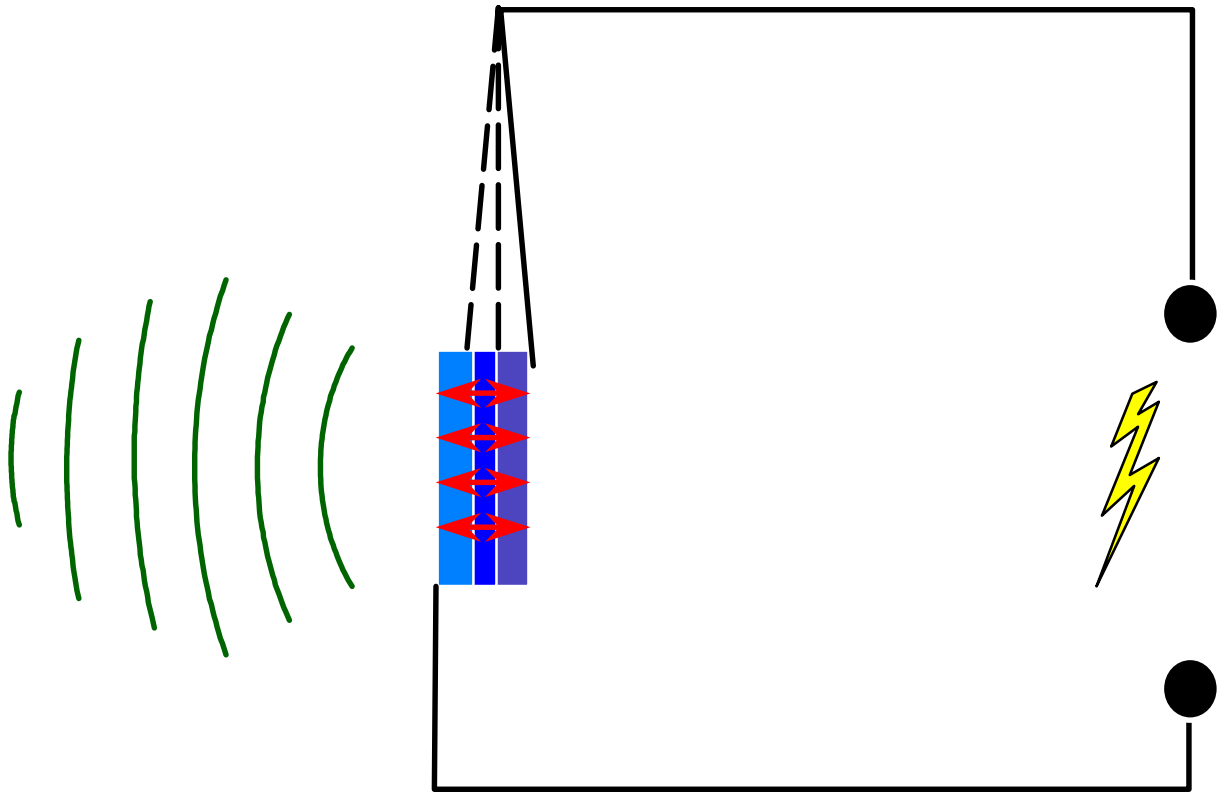
The effect inverses with polarity change

Piezoelectric Effect



An alternating voltage generates crystal oscillations at the frequency f

Piezoelectric Effect

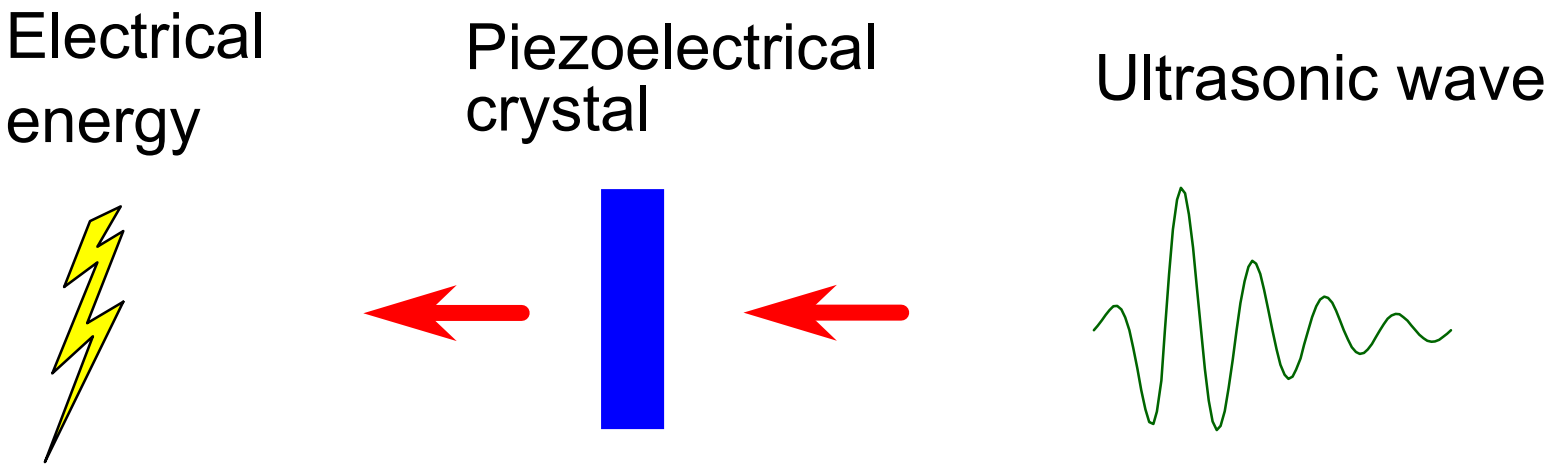


A short voltage pulse generates an oscillation at the crystal‘s resonant

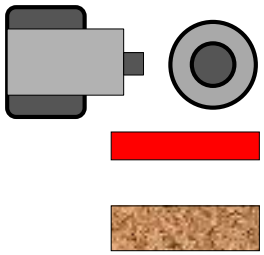
frequency f_0

Reception of ultrasonic waves

A sound wave hitting a piezoelectric crystal, induces crystal vibration which then causes electrical voltages at the crystal surfaces.



Ultrasonic Probes



socket

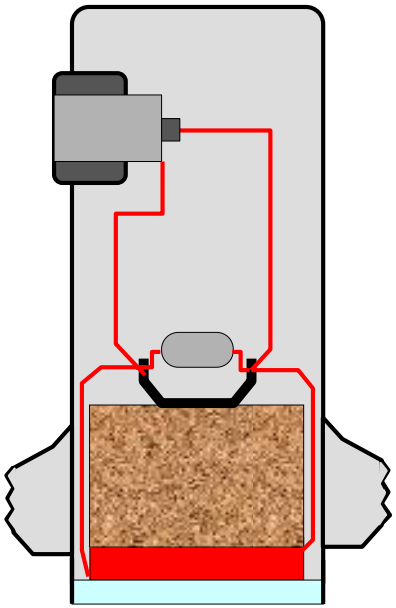
crystal

Damping

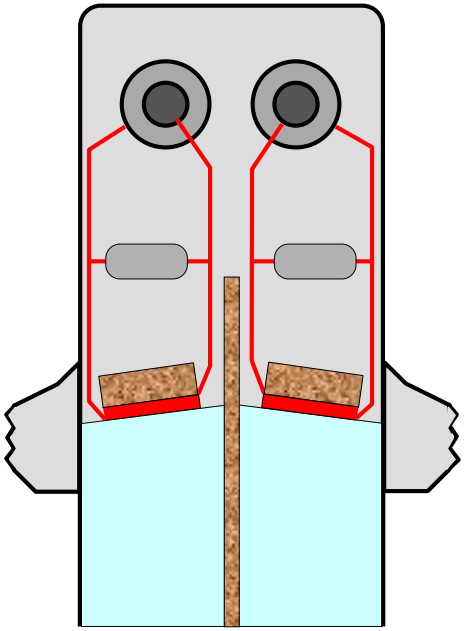
Delay / protecting face

Electrical matching

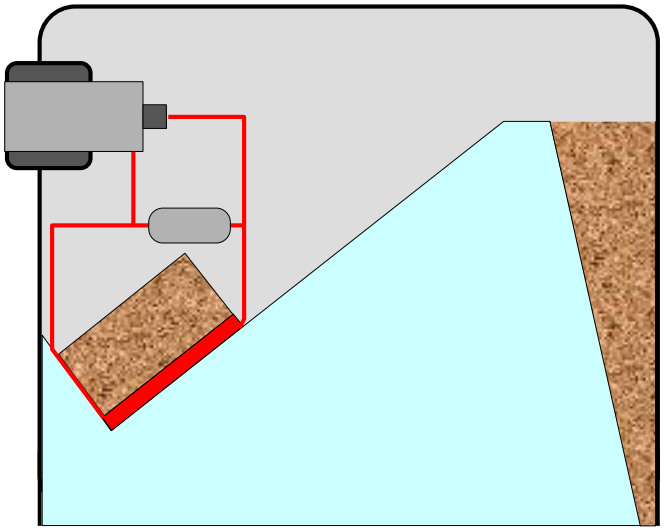
Cable



Straight beam probe

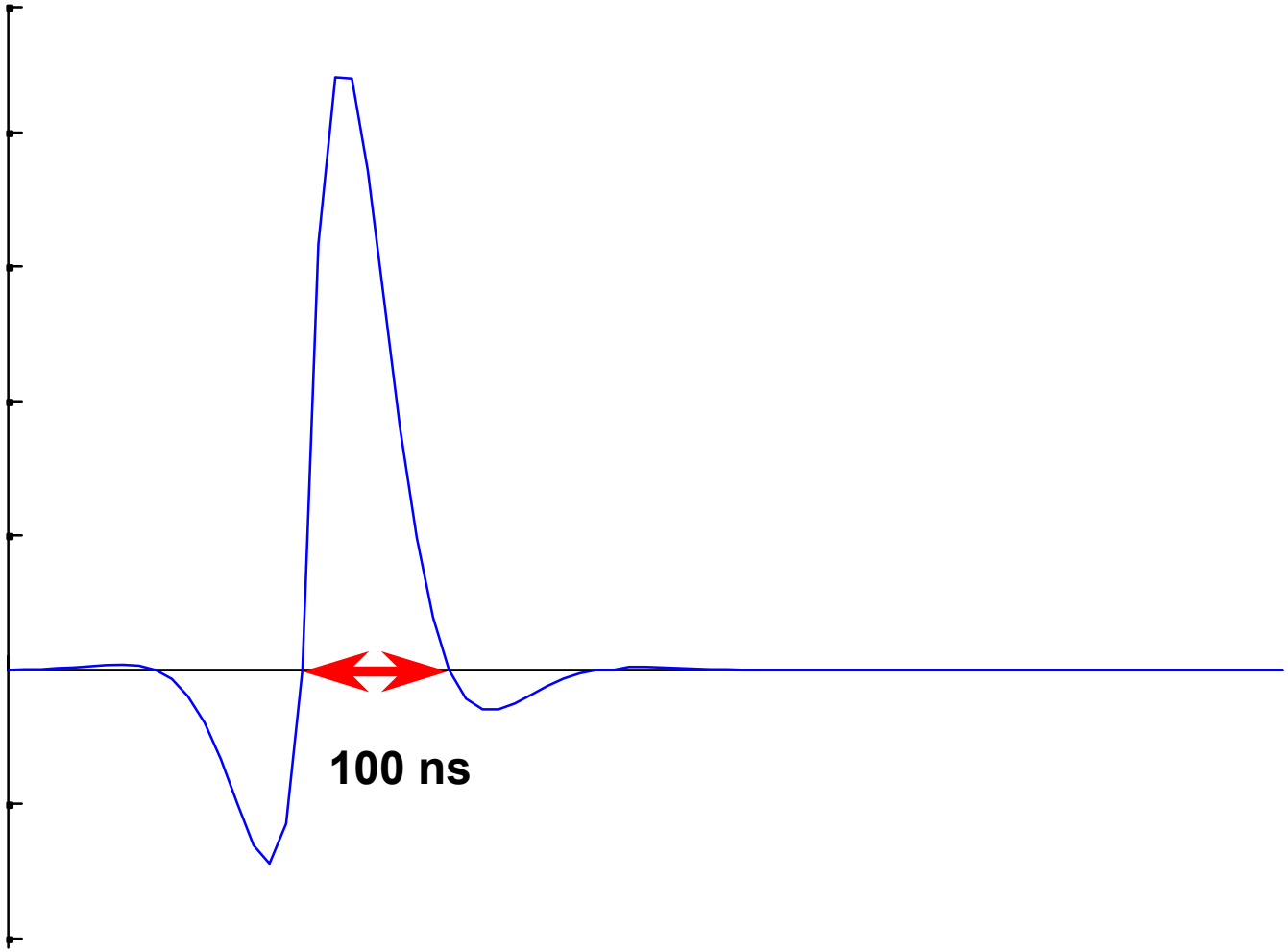


TR-probe

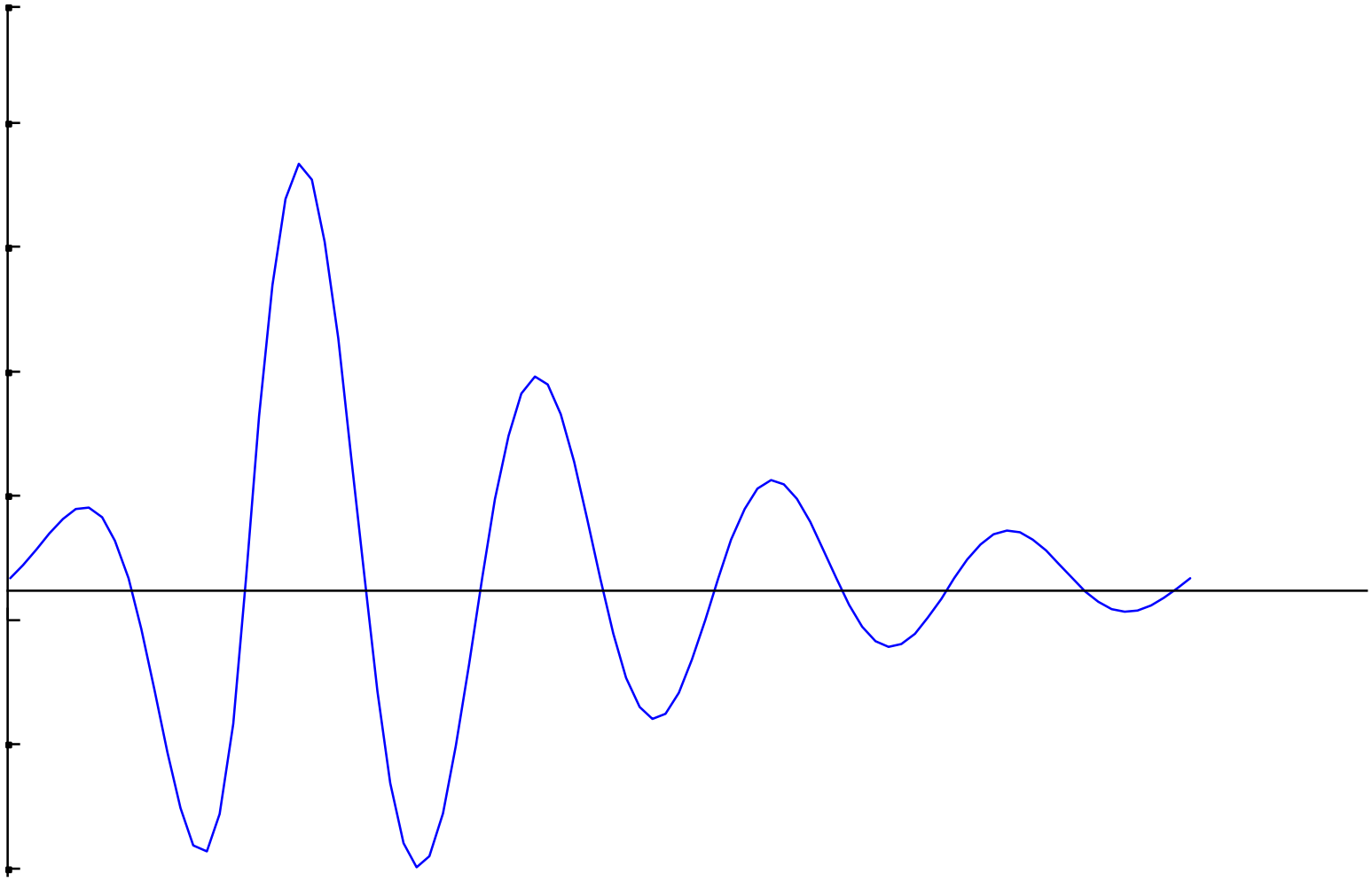


Angle beam probe

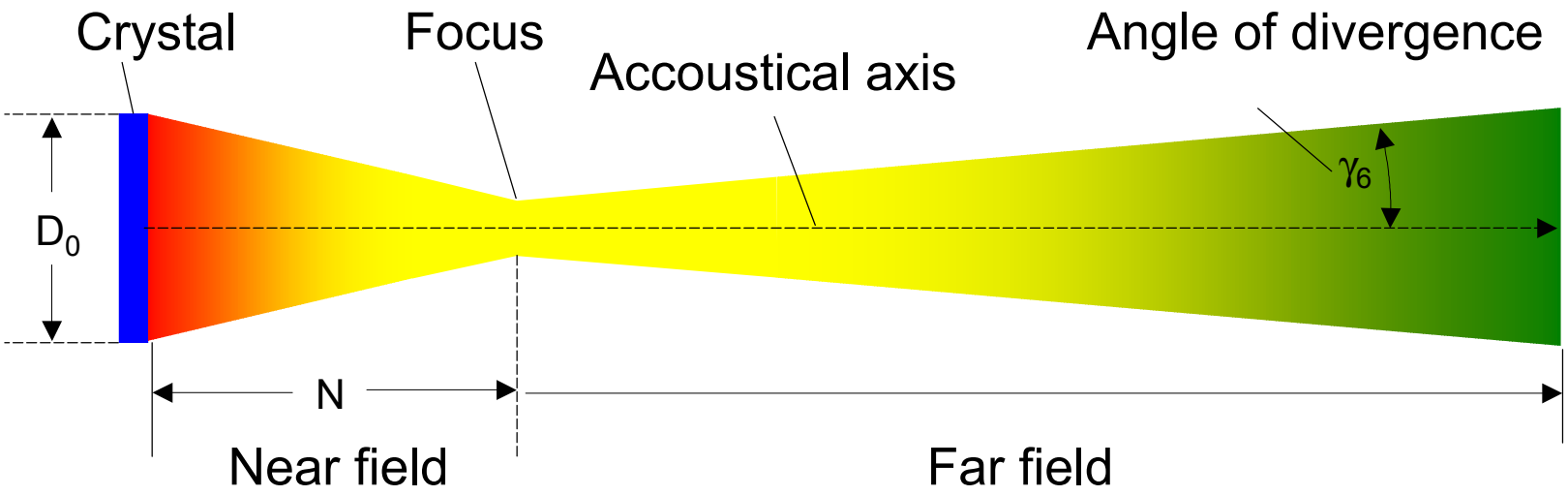
RF signal (short)



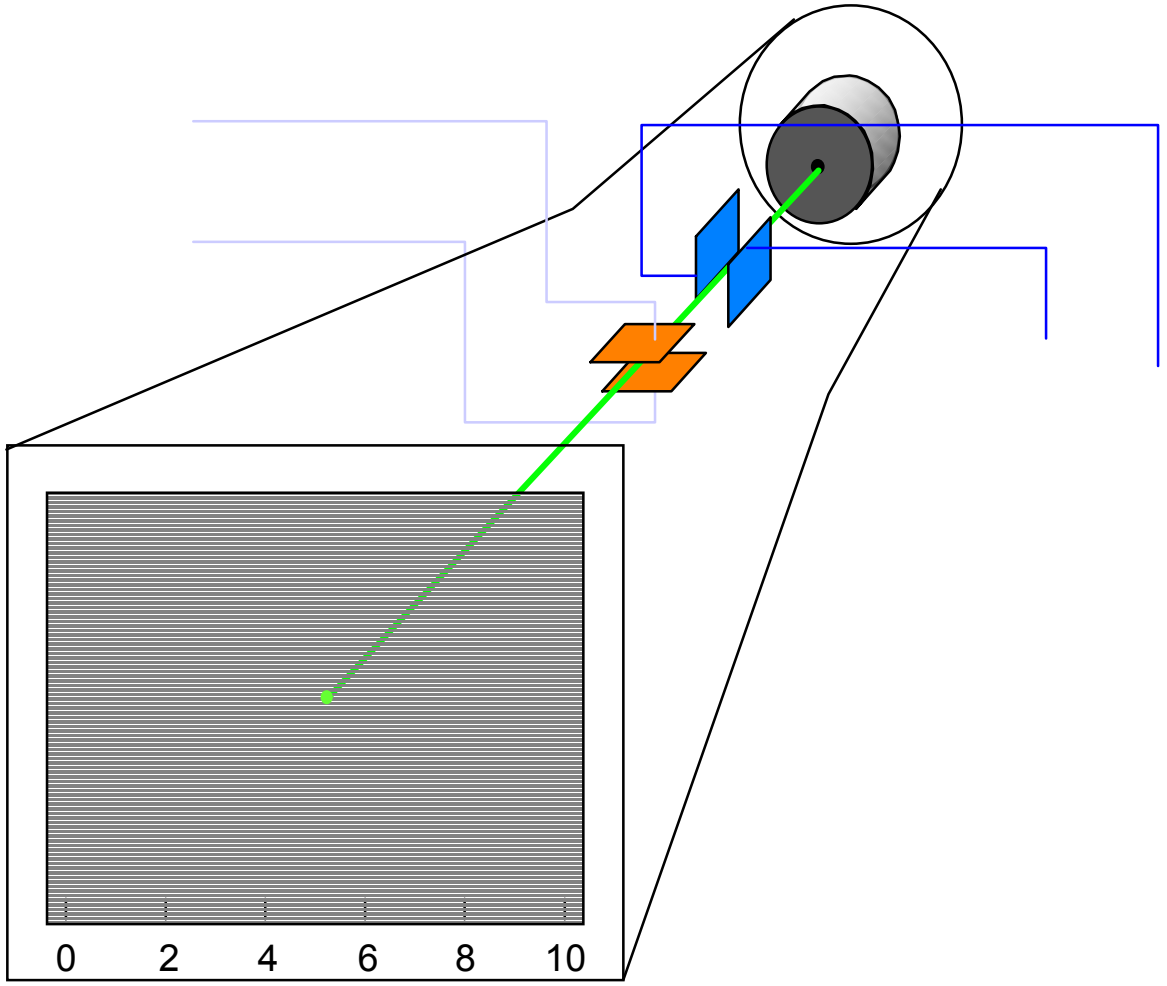
RF signal (medium)



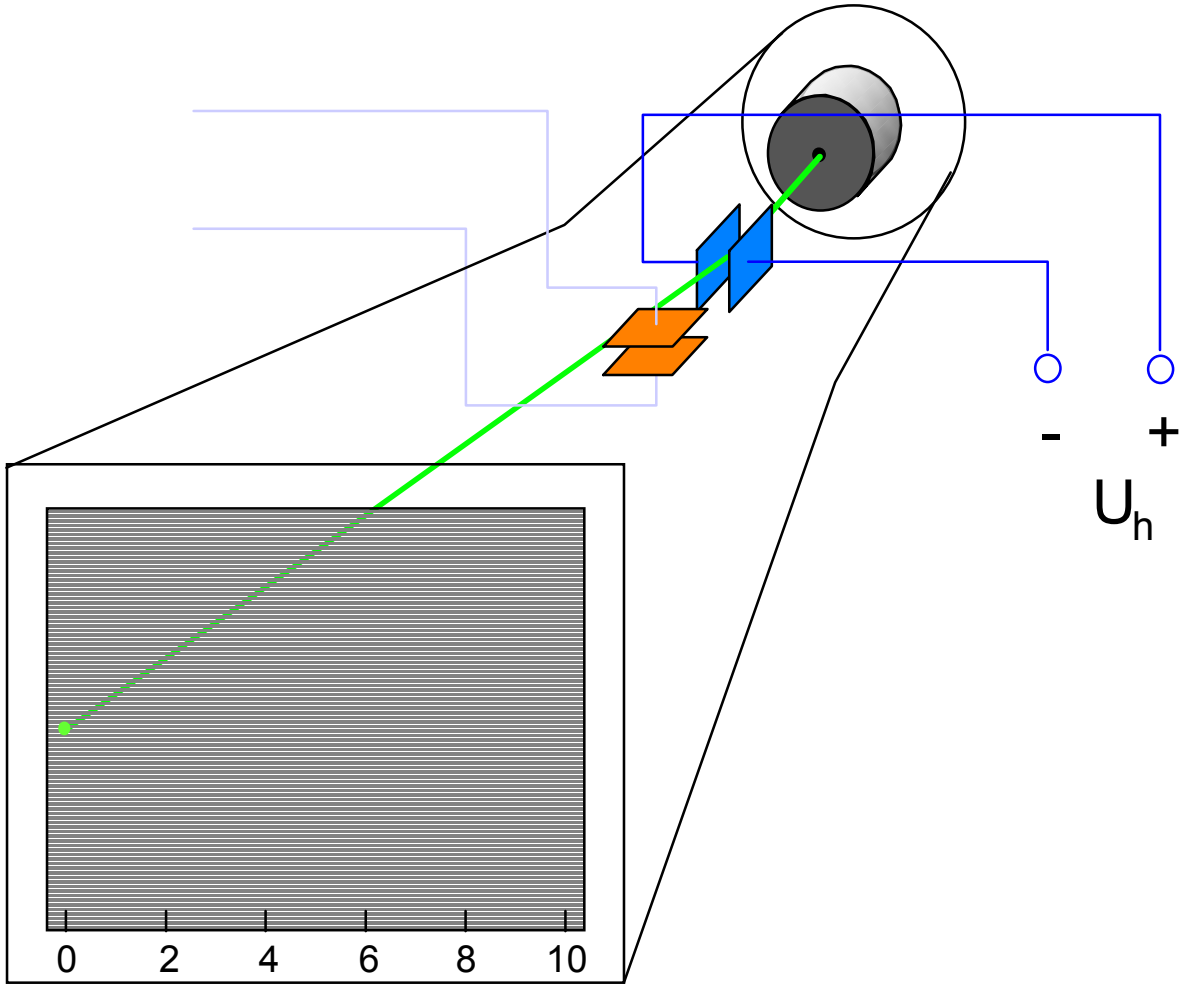
Sound field


Crystal
Focus
Accoustical axis
Angle of divergence
γ_6
D_0
N
Near field
Far field

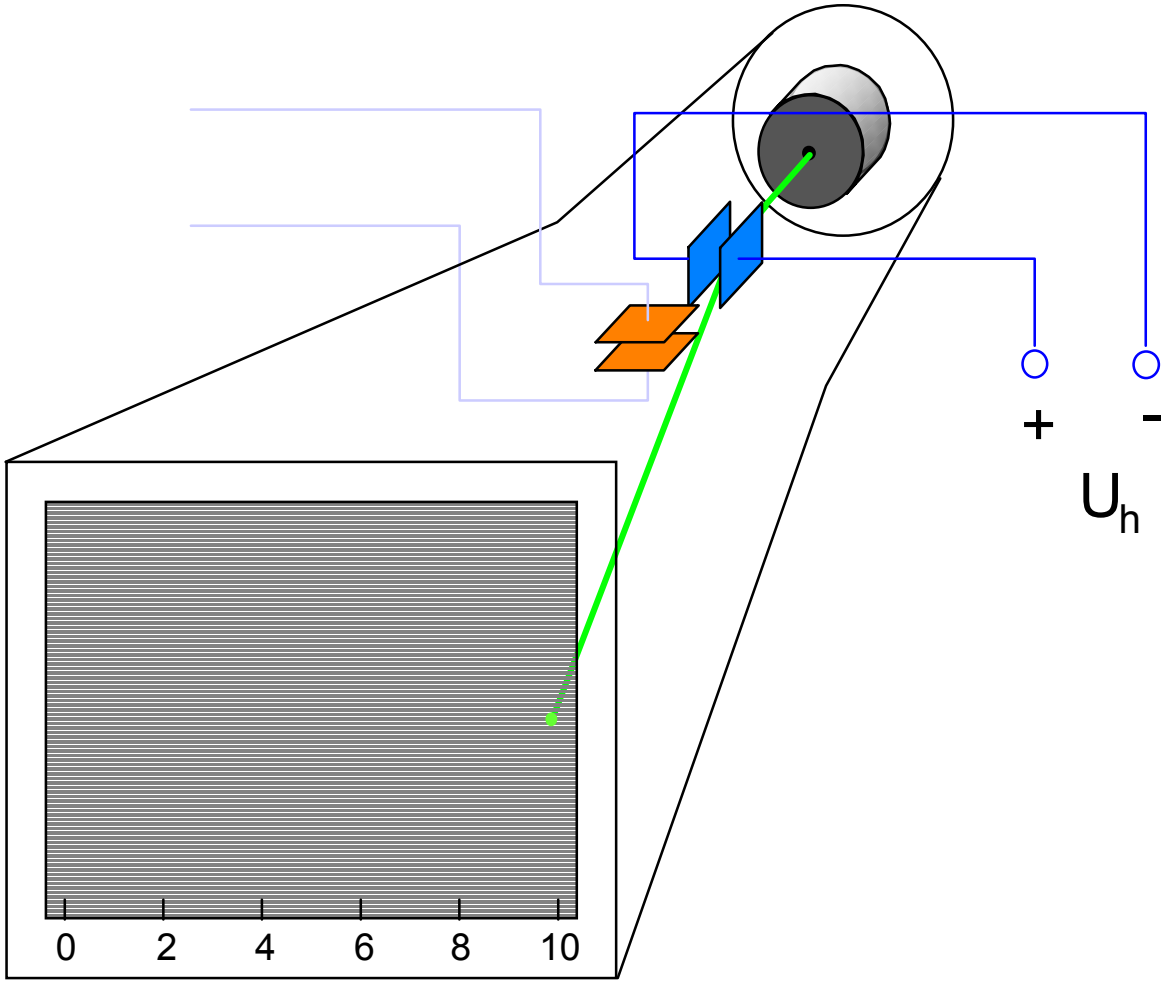
Ultrasonic Instrument



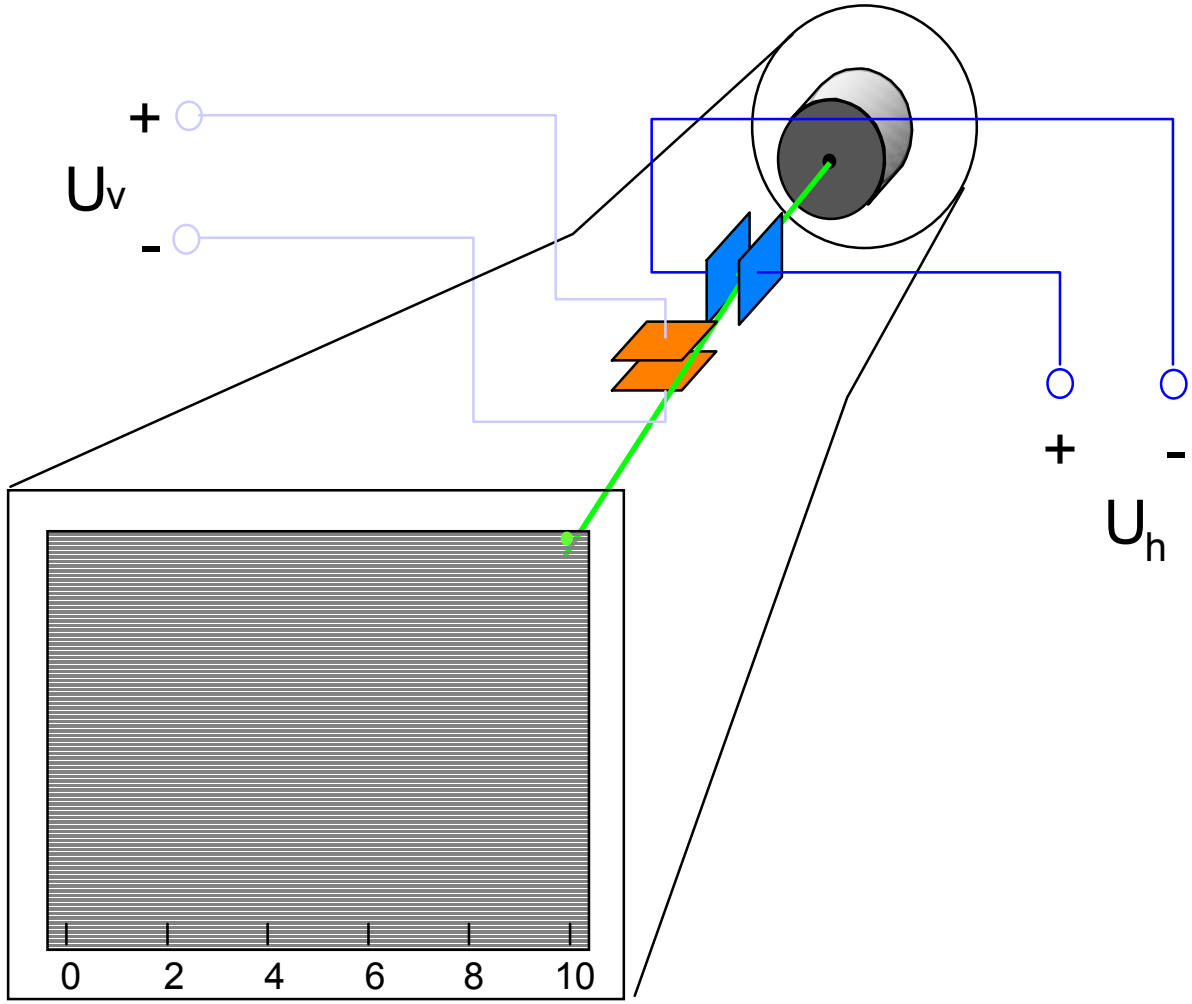
Ultrasonic Instrument



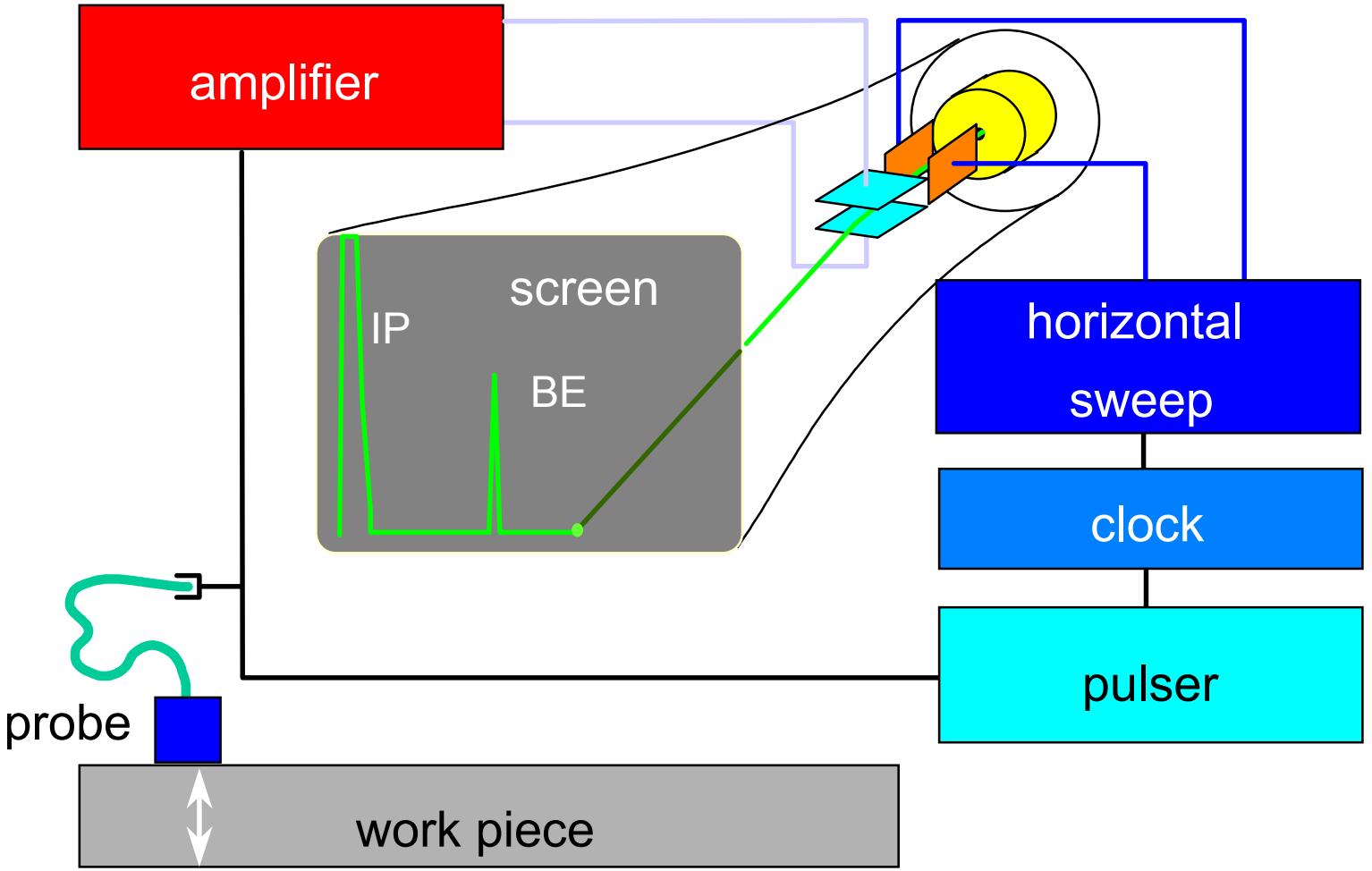
Ultrasonic Instrument



Ultrasonic Instrument



Block diagram: Ultrasonic Instrument



Sound reflection at a flaw

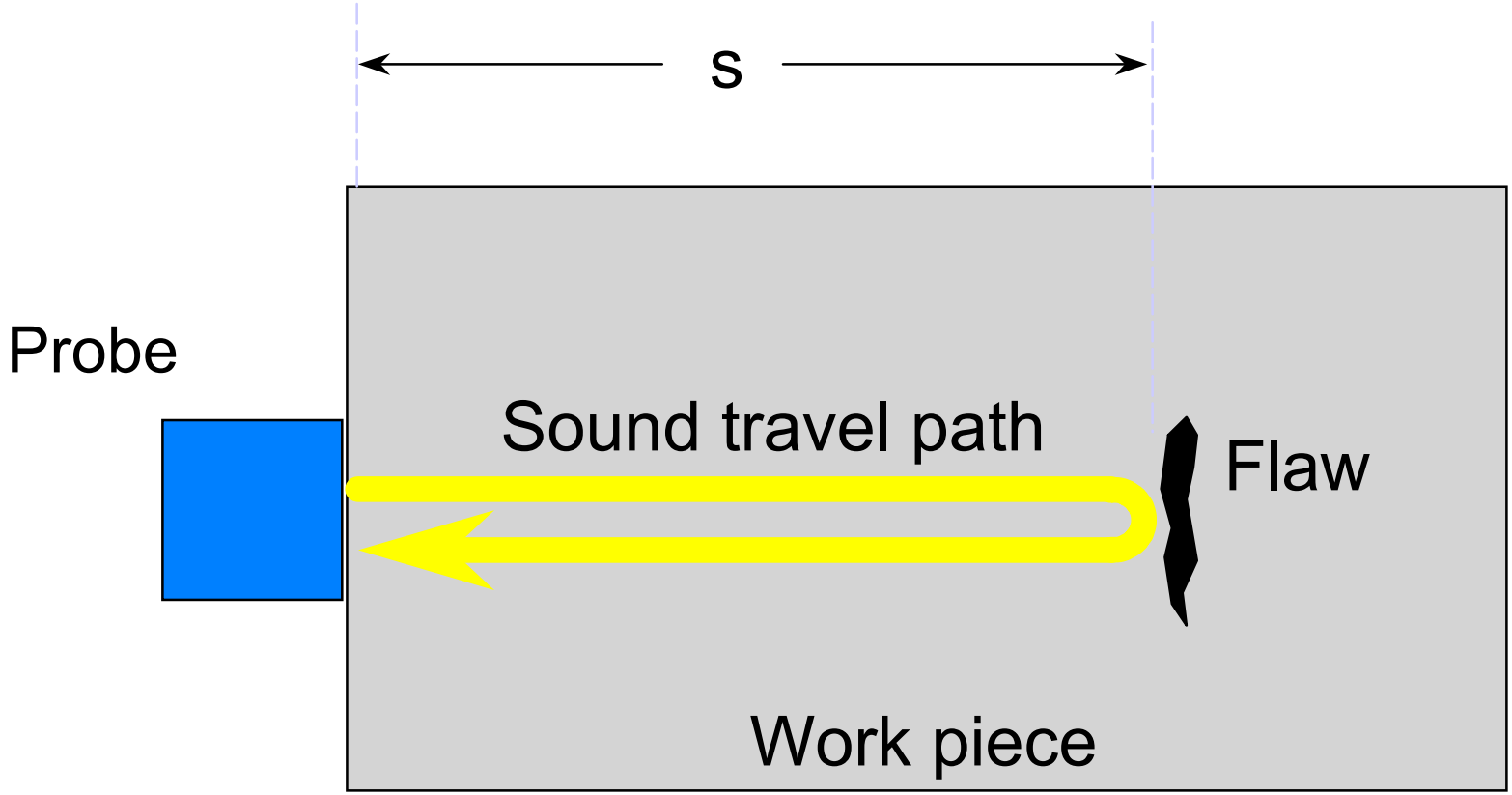
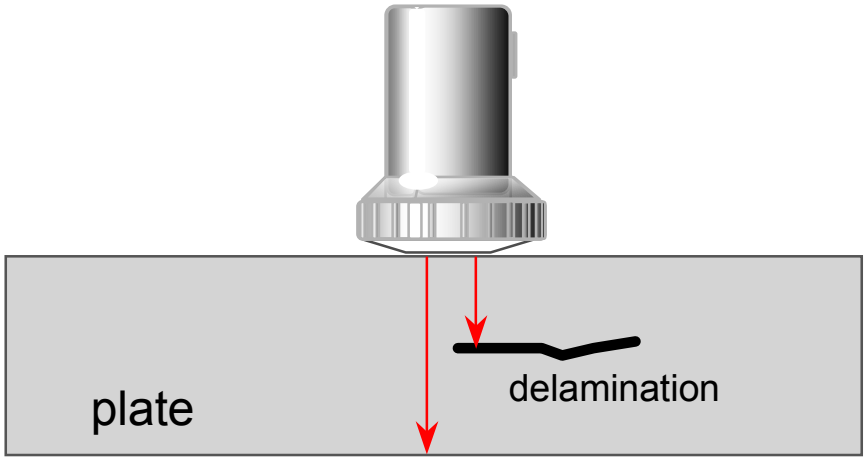
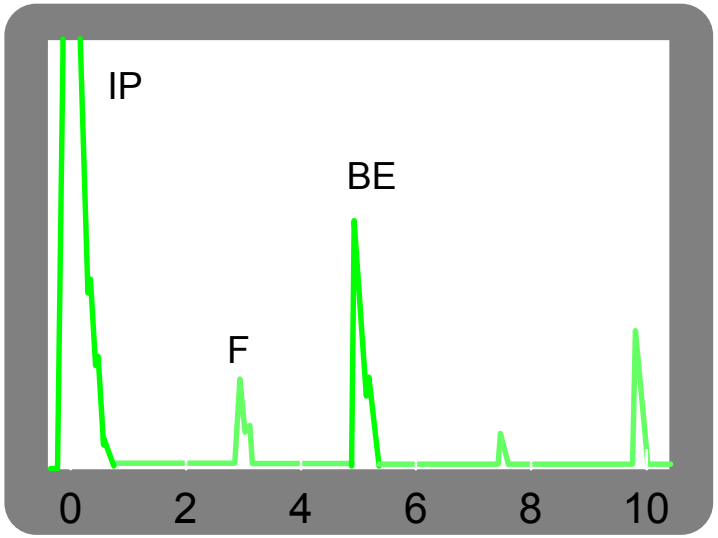


Plate testing



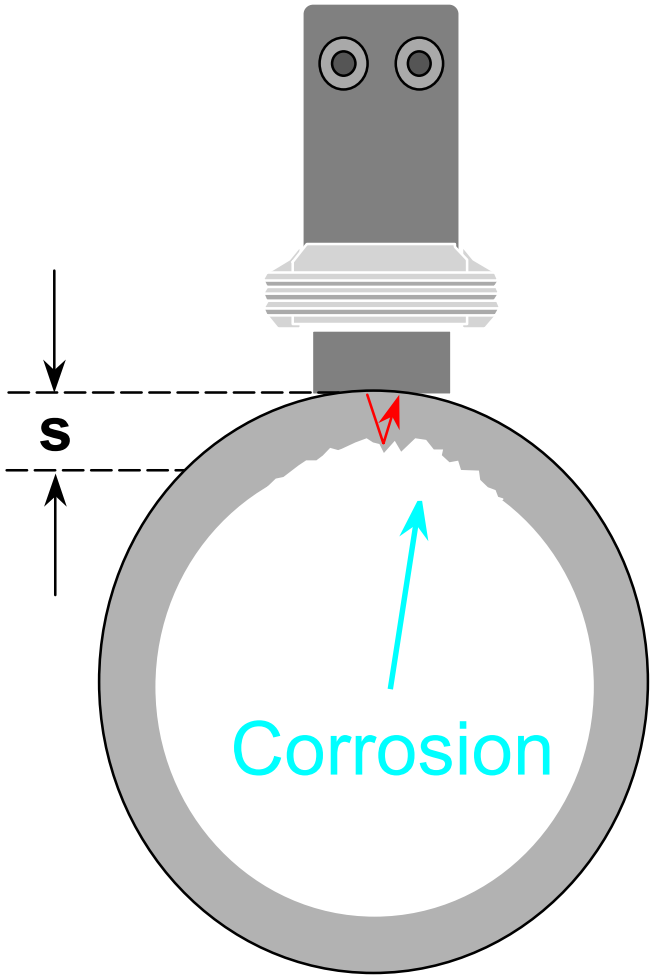


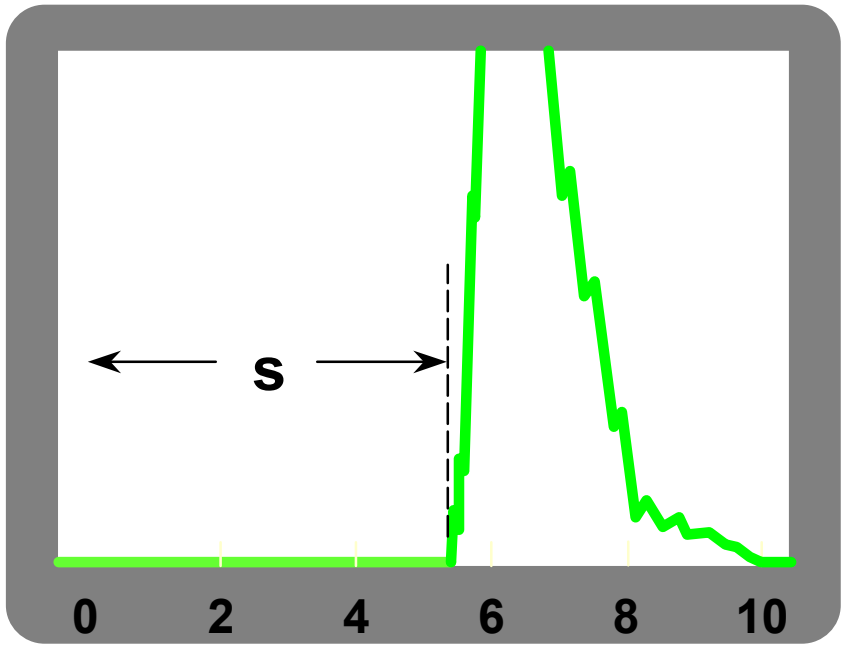
IP = Initial pulse

F = Flaw

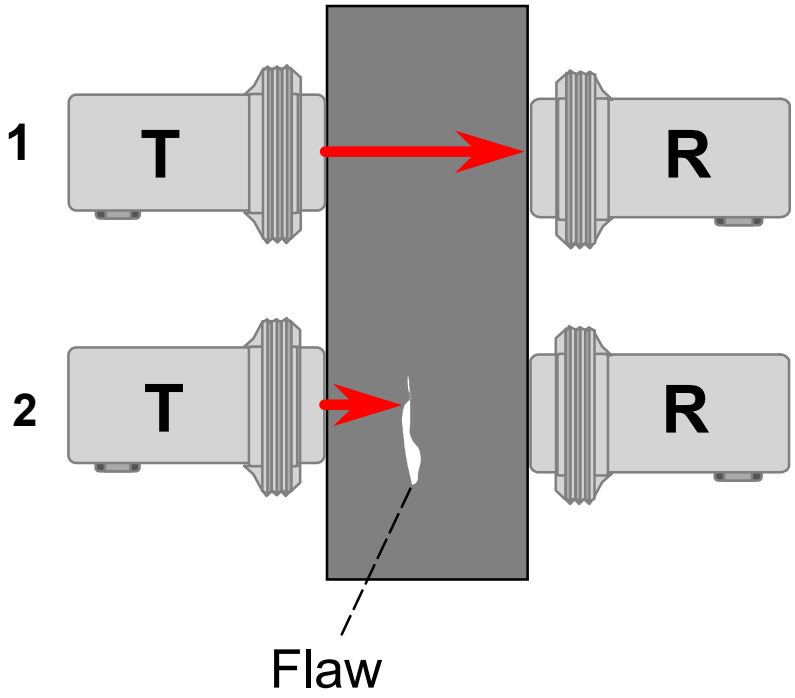
BE = Backwall echo

Wall thickness measurement

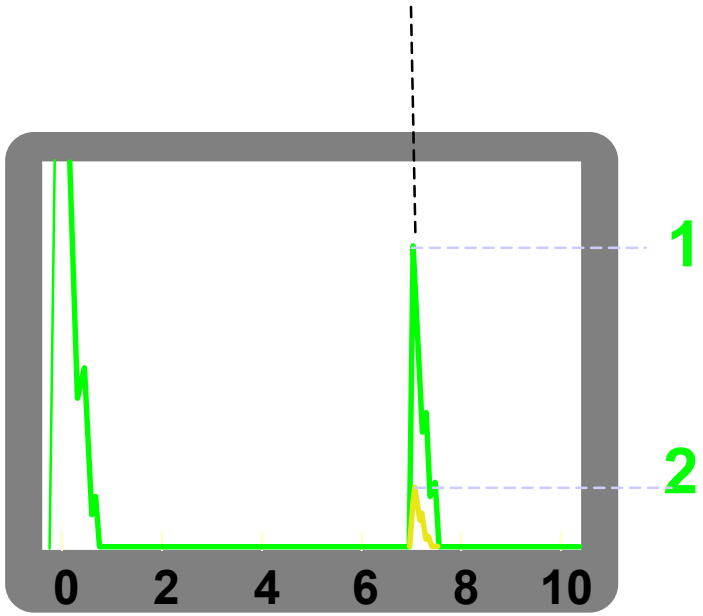




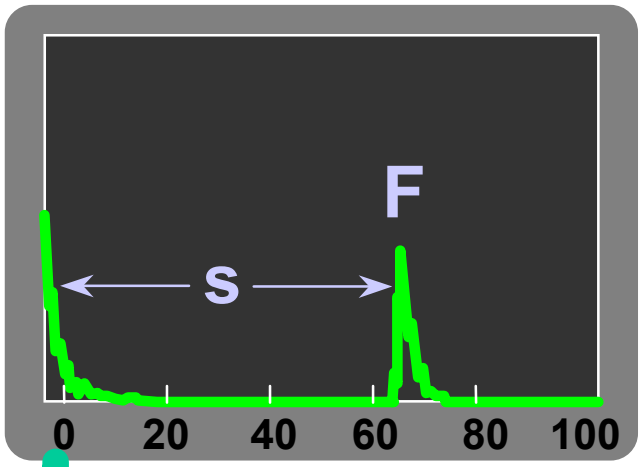
Through transmission testing



Through transmission signal



Weld inspection



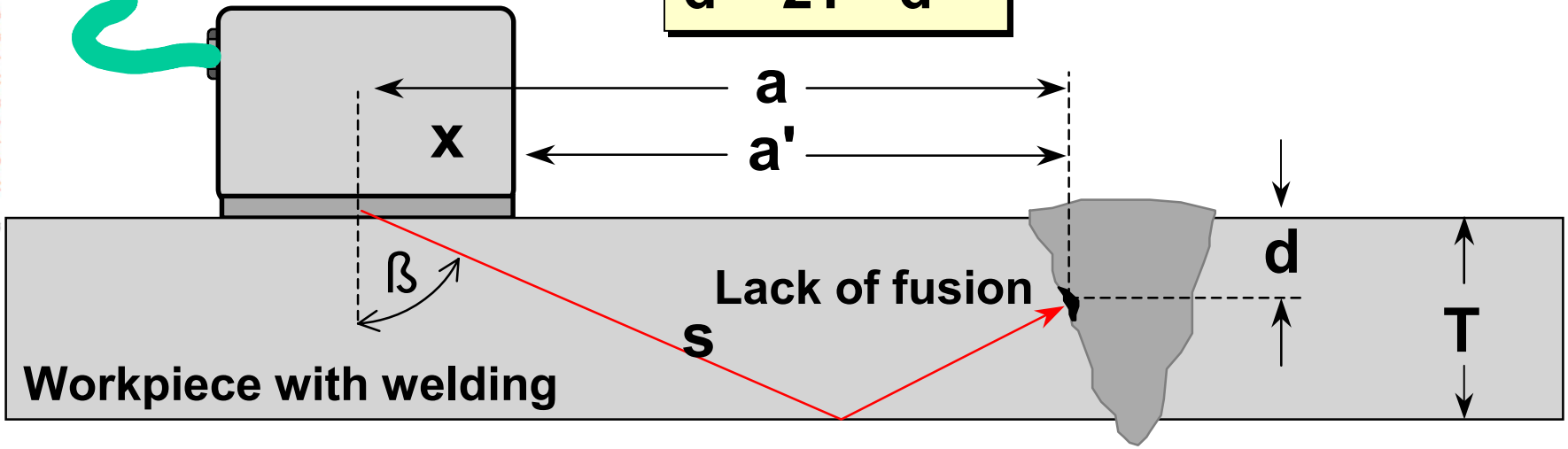
$a = s \sin ß$

$a' = a - x$

$d' = s \cos ß$

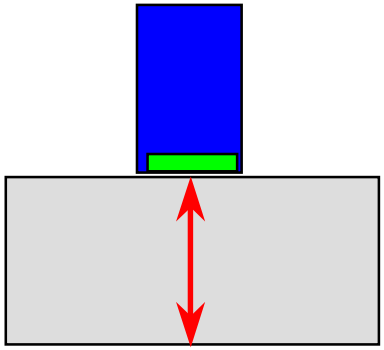
$d = 2T - d'$

ß = probe angle
s = sound path
a = surface distance
a‘ = reduced surface distance
d‘ = virtual depth
d = actual depth
T = material thickness

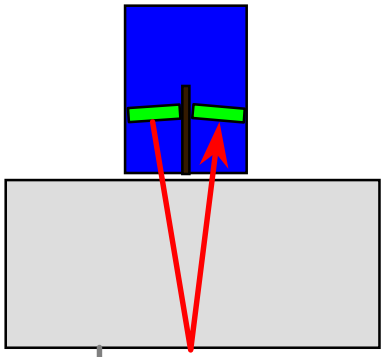


Straight beam inspection techniques:

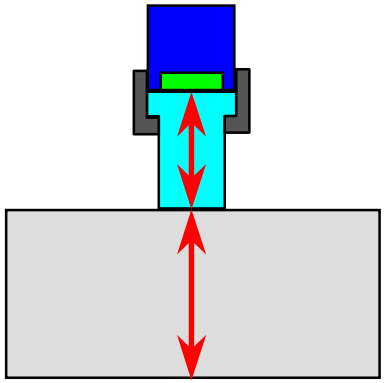
Direct contact,
single element probe



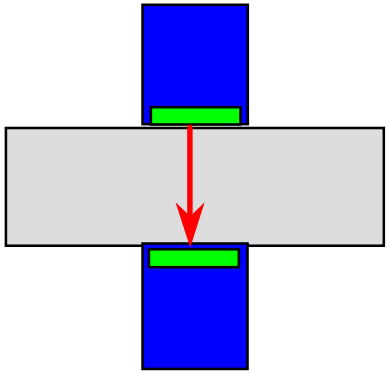
Direct contact,
dual element probe



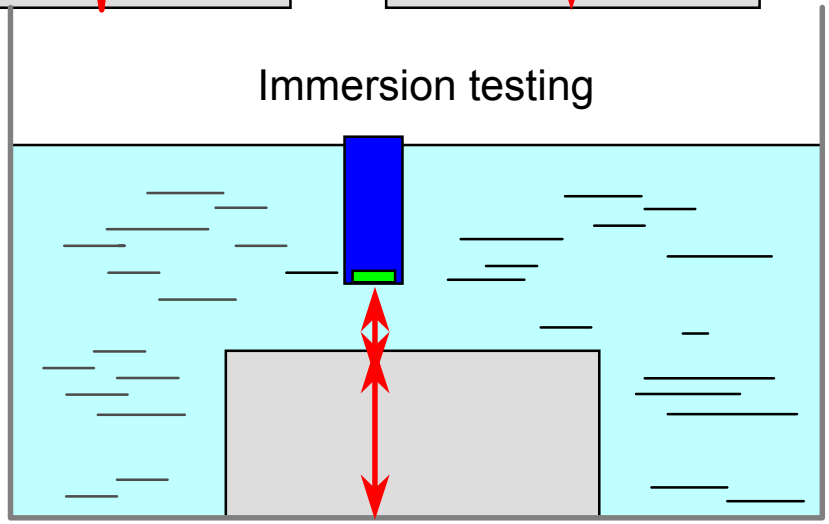
Fixed delay



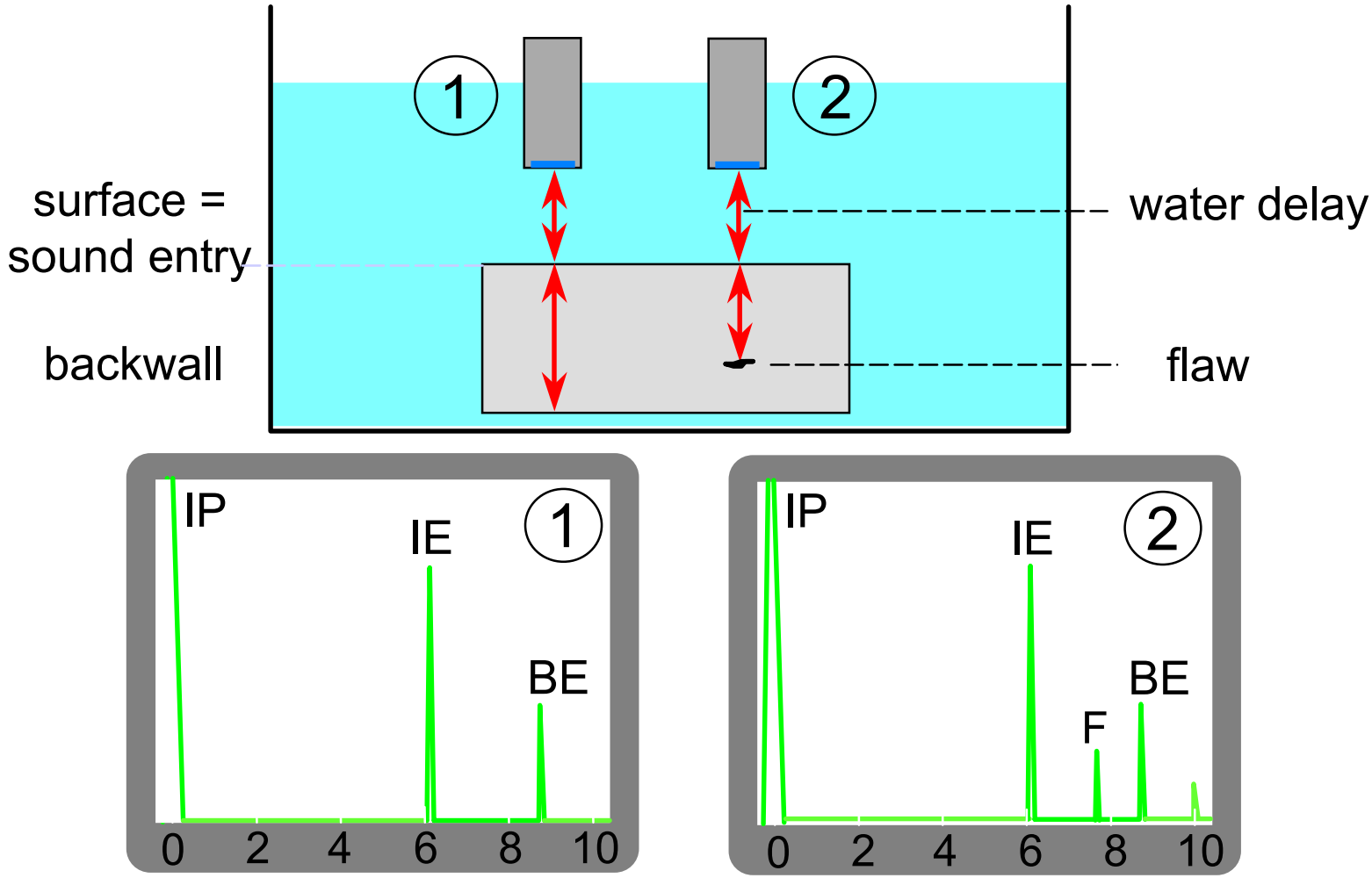
Through transmission



Immersion testing



Immersion testing



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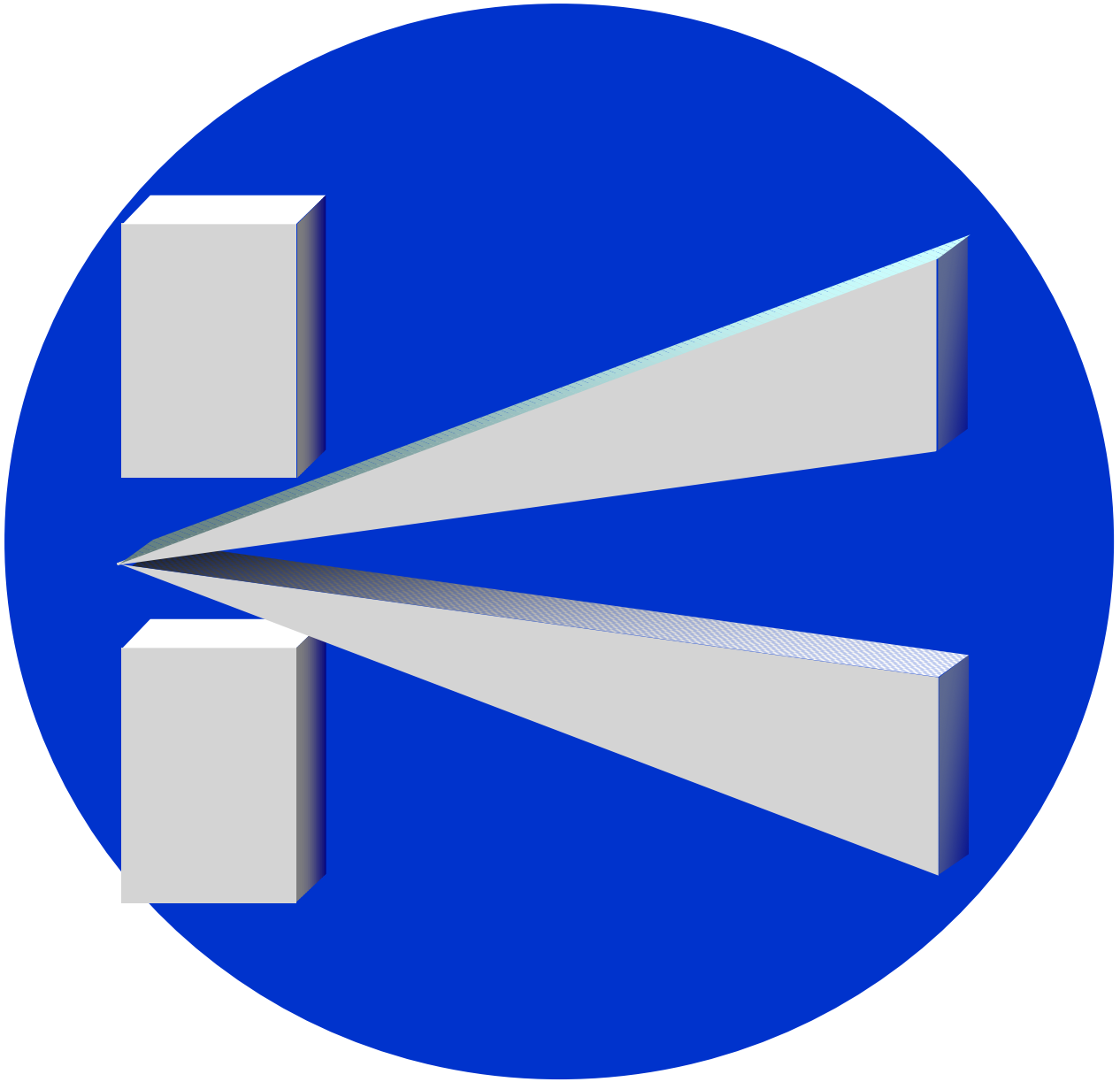

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